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MBA PROFESSIONAL REPORT

Cost Analysis of Utilizing Electric Vehicles and Photovoltaic Solar Energy in the United States Marine Corps Commercial Vehicle Fleet

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December 2009

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COST ANALYSIS OF UTILIZING ELECTRIC VEHICLES AND PHOTOVOLTAIC SOLAR ENERGY IN THE UNITED STATES MARINE CORPS COMMERCIAL VEHICLE FLEET

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Submitted in partial fulfillment
of the requirements for the degree of

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ABSTRACT

The purpose of this MBA project is to examine the upfront cost associated with purchasing electric vehicles and installing photovoltaic (PV) solar energy for the Federal Fleet at Marine Corps Logistics Base (MCLB) Barstow. The goal of this project is to provide a present value acquisition cost analysis for implementing Low Speed Vehicle (LSV), Pure Electric Vehicles (PEV), and PV solar electric energy in the United States Marine Corps commercial vehicle fleet at Marine Corps Logistics Base Barstow.

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LIST OF ACRONYMS AND ABBREVIATIONS

AC	Alternating Current
AFV	Alternative Fuel Vehicles
AMFA	Alternative Motor Fuel Act of 1988
BOS	Balance of Systems
CNG	Compressed Natural Gas
DC	Direct Current
DoE	Department of Energy
DoT	Department of Transportation
EISA 2007	Energy Independence and Security Act of 2007
EO 13423	Executive Order 13423
EPA	Environmental Protection Agency
EPAct 1992	Energy Policy Act of 1992
EPAct 2005	Energy Policy Act of 2005
EV1	Electric Vehicle 1
EVC	Electric Vehicle Company
FEMP	Federal Energy Management Program
FMVSS	Federal Motor Vehicle Safety Standards and Regulations
FY	Fiscal Year
GAO	Government Accountability Office
GEM	Global Electric Motorcars
GM	General Motors
GME	Garrison Mobile Equipment
GSA	General Services Administration
ICE	Internal Combustion Engine
kWh	Kilowatt/hours
LSV	Low-Speed Vehicles
MCLB	Marine Corps Logistics Base
MIT	Massachusetts Institute of Technology

NASA	National Aeronautics and Space Administration
NDAA 2008	National Defense Authorization Act of 2008
NEV	Neighborhood Electric Vehicles
NREL	National Renewable Energy Laboratory
OMB Cir A-94	Office of Management and Budget Circular No. A-94
PEV	Pure Electric Vehicle
PIH	Plug-in Hybrid
PV	Photovoltaic solar energy
R&D	Research and Development
SAIC	Science Applications International Corporation
SUT	Sports Utility Truck
SUV	Sports Utility Vehicle
USMC	United States Marine Corps
VIN	Vehicle Identification Number

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I. INTRODUCTION

A. BACKGROUND

The *Energy Policy Act* of 1992, *Executive Order 13423*, and the *Energy Independence and Security Act* of 2007 mandate that Federal Fleets reduce their consumption of foreign oil. Federal Fleets must reduce petroleum consumption by 2% each year until the year 2015. In support of reducing the nation's dependence on foreign oil, President Barrack Obama authorized $300 million in the *American Recovery and Reinvestment Act* of 2009 for the procurement of Alternative Fuel Vehicles (AFV). The goals of the additional funding are to increase fuel efficiency and reduce vehicle emissions. In order to comply with legislation, this project is researching the transition to pure electric vehicles (PEV) and photovoltaic (PV) solar energy at Marine Corps Logistics Base (MCLB) Barstow.

B. MCLB BARSTOW

Located on Interstate 15 between Los Angeles, California, and Las Vegas, Nevada, MCLB Barstow is the Marine Corps' only maintenance depot on the West Coast. The base consists of two major annexes, Nebo and Yermo, which are seven miles apart. The Nebo Annex consists of 1,879 acres and serves as Command Headquarters and an area for storage, shopping, and housing (Marine Corps Logistics Base Barstow, 2009). The Yermo Annex consists of 1,859 acres and serves as the major maintenance complex and an area for storage, and industry (Marine Corps Logistics Base Barstow, 2009). Daily interaction between the Nebo and Yermo Annex personnel is required to ensure successful mission completion.

To support MCLB Barstow's mission, the Marine Corps has stationed Garrison Mobile Equipment (GME), a Federal Fleet, and a GME fleet manager at MCLB Barstow. *Marine Corps Order P11240.106B* defines GME as the following: "GME consists of commercially available owned, leased, or otherwise controlled passenger vehicles, cargo

vehicles, material handling equipment, engineer equipment, and railway rolling stock" (McKissock, 2000, p. 1–3) This equipment is essential to daily operations aboard MCLB Barstow and to the interaction between the Nebo and Yermo Annexes.

The GME fleet manager is responsible for maintaining the Federal Fleet in support of MCLB Barstow. *Marine Corps Order P11240.106B* defines the role of the fleet manager as the following: "GME fleet managers operate the GME fleets in support of transportation and maintenance requirements at Marine Corps activities. They will not use their GME fleet for tactical purposes, nor will they deploy GME asset" (McKissock, 2000, p. 1–3).

The fleet manager at MCLB Barstow is responsible for hundreds of assets, but this study will focus on Low-speed Vehicles (LSV) and Internal Combustion Engine (ICE) vehicles in MCLB Barstow's GME fleet.

C. LEGISLATION

Consumption of foreign oil in the U.S. substantially out-weighs the nation's oil production capabilities, resulting in weakened national security. A study conducted by RAND Corporation and sponsored by the Institute for 21st Century Energy states, "The United States consumes 25% of all the oil produced in the world, yet the United States accounts for only 10% of world oil production" (Crane et al., 2009, p. xiii). The study also reports that in 2007, the United States imported 58% of the oil it consumed (Crane et al., 2009, p. xiii).

President Barrack Obama, former President George W. Bush, and other members of the United States Government have acknowledged the nation's dependence on foreign oil. In remarks made by President Barrack Obama on January 26, 2009, concerning jobs, energy independence, and climate change, he stated the following: "At a time of such great challenge for America, no single issue is as fundamental to our future as energy. America's dependence on oil is one of the most serious threats that our nation has faced" (Phillips, 2009). President Barrack Obama's remarks echo the same concerns former President George W. Bush expressed in his 2007 State of the Union Address. David Sanger from *The New York Times* recorded former President Bush as stating, "For too

long our nation has been dependent on foreign oil. And this dependence leaves us more vulnerable to hostile regimes, and to terrorists, who could cause huge disruptions of oil shipments and raise the price of oil and do great harm to our economy” (Sanger, 2007). The leadership of America has recognized the relationship between the nation’s dependence on foreign oil and national security. Since 1988, the United States Government has implemented legislative laws and regulations to free the country from its dependence on oil and to reduce toxic emissions from vehicles.

In an attempt to reduce dependence on foreign oil and reduce toxic emissions from vehicles, the United States Government has implemented several legislative laws and regulations directed towards Federal Fleets. A Federal Fleet can be defined as a motor vehicle fleet that is operated by a federal agency or department. A few examples of an agency or department within Federal Fleets are the United States Marine Corps (USMC), the Department of Homeland Security, and the Department of Treasury. According to the Federal Fleet Report of 2008, there are 46 departments or agencies responsible for the management of over 645,000 vehicles in the Federal Fleet (General Services Administration, 2009, p. 11).

The USMC motor vehicle fleet is a Federal Fleet that is required to adhere to several legislative laws and regulations. These laws and regulations consist of Executive Orders from the President of the United States, energy policy acts, the *Energy Independence and Security Act* of 2007, and the *National Defense Authorization Act* of 2008. The overarching goal of legislation and regulations for Federal Fleets is to reduce the nation’s dependence on foreign oil, decrease toxic vehicle emissions, and provide milestones for Federal Fleets.

1. History of Federal Fleet Legislation and Current Initiatives

In 2008, the Federal Energy Management Program (FEMP) prepared a chronological report highlighting the history and mandates influencing Federal Fleets. FEMP begins its historical review of legislation in 1988, when the United States

Government initiated the first legislation on Federal Fleets. Appendix A contains the full FEMP report, *History of Actions and Mandates Relative to Federal Fleets, Alternative Fuel Vehicles, and Alternative Fuel Use*.

Current initiatives influencing Federal Fleets, the nation's dependence on foreign oil, and vehicle emissions are discussed in the 2009 Government Accountability Office (GAO) report number GAO-09-493, *Federal Energy and Fleet Management*. The report highlights the *Energy Policy Act* of 1992 (EPAct 1992), *Energy Policy Act* of 2005 (EPAct 2005), *Energy Independence and Security Act* of 2007 (EISA 2007), and *Executive Order 13423*. Below are highlights pertaining to Federal Fleet legislation.

- EPAct 1992
    - This act mandates that Federal Fleets of 20 or more vehicles located in a metropolitan area acquire AFV. Starting in 1999, the legislation mandates that 75% of all vehicle acquisitions be AFV (GAO, 2009, p. 6). EPAct 1992 defines alternative fuel as:

> Methanol, denatured ethanol, and other alcohols; mixtures containing 85 percent or more by volume of methanol, denatured ethanol, and other alcohols with gasoline or other fuels; natural gas; liquefied petroleum gas; hydrogen; coal-derived liquid fuels; fuels derived from biological materials; electricity and any other fuel the Secretary determines, by rule, is substantially not petroleum and would yield substantial energy benefits and substantial environmental benefits. (U.S. Congress, 1992, Sec. 301)

- EPAct 2005
    - This act mandates that all AFV utilize alternative fuel unless a waiver has been granted from the Department of Energy (Department of Energy, Office of Energy Efficiency and Renewable Energy, 2009, p. 1)
- EISA 2007
    - GAO-09-493 highlights the following requirements in EISA 2007
        - Prohibits acquisition of light-duty and medium-duty passenger vehicles that are not low greenhouse gas emitting vehicles (GAO, 2009, p. 6–7)
        - Mandates the decrease of annual vehicle petroleum by 20% based on a 2005 baseline (GAO, 2009, p. 6–7)
        - By 2015 and every year after, increases alternative fuel consumption by 10% based on a 2005 baseline (GAO, 2009, p. 6–7)

- Executive Order 13423
    - This Executive Order mandates requirements for Federal Fleets consisting of 20 or more vehicles. GAO-09-493 states that Executive Order 13423 requires “federal agencies operating fleets of 20 or more vehicles to begin using plug-in hybrids when these vehicles become commercially available and can be purchased at a cost reasonably comparable to conventional vehicles based on life-cycle costs.” (GAO, 2009, p. 6)

D. OBJECTIVE

The objective of this project is to provide a present value acquisition cost analysis for implementing LSVs, PEVs, and PV solar energy in the United States Marine Corps commercial vehicle fleet at MCLB Barstow. This project’s objectives are the following.

- Present an overview of the current technologies in LSVs, PEVs, and PV solar energy
- Develop a model for estimating up-front costs associated with transitioning the current Federal Fleet at MCLB Barstow to a fleet with LSVs and PEVs
- Develop a model for estimating up-front costs associated with generating sufficient PV solar energy to recharge the recommended LSV and PEV fleets at the Nebo and Yermo Annexes

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II. LITERATURE REVIEW

This project began with a literature review of LSV, PEV, and PV solar energy. LSV literature focused on history, laws, capabilities, range and basic vehicle components. PEV literature considered history, resurgence, and components. Lastly, the project researched PV solar energy history, photoelectric effect, PV systems, and components.

A. LOW-SPEED VEHICLES

In April of 1998, Global Electric Motorcars (GEM) manufactured its first LSV, also known as Neighborhood Electric Vehicles (NEV). The first GEM LSV was completely electric and had the capability to transport two passengers and reach a maximum speed of 20 mph. Shortly after the first production of the LSV by GEM, the U.S. Department of Transportation (DoT) recognized the LSV as a new class of motor vehicle (Global Electric Motorcars, 2008).

In June of 1998, an LSV was defined by the DoT in the Federal Motor Vehicle Safety Standards and Regulations (FMVSS) under Standard No. 500. FMVSS Standard No. 500 defines an LSV as:

> A low-speed vehicle is a 4-wheeled motor vehicle, other than a truck, whose attainable speed is more the 32 km/h (20 mph) and not more than 40 km/h (25 mph). The standard requires ten specific items of safety equipment. (National Highway Traffic Safety Administration, 1998)

The recognition of the LSV as a motor vehicle allowed usage of these vehicles on public roadways where posted speed limits were below 35 mph.

1. Safety Requirements and California Law

To ensure the safety of LSV users and safe utilization on public roadways, the DoT requires LSVs to meet several safety requirements. The safety standards are outlined in FMVSS Standard No. 500, Section 571.500 of Title 49 of the Code of Federal Regulations and are mandatory for all LSVs operating on public roadways (Department of Transportation, 2003):

In addition to safety standards and regulations established by the DoT, individual states can implement legislation affecting LSVs operating on public roadways. The state of California addresses regulations regarding the utilization of LSVs in California Vehicle Codes 21250–21266. The California Vehicle Code allows LSVs on public roadways where the posted speed limit is below 35 mph. California mandates that all LSVs conform to all safety regulations in FMVSS section 571.500 of Title 49 of the Code of Federal Regulations. To ensure the safety of the public, California reserves the right to prohibit the use of LSVs on any roadways that may not be in the best safety of the community (Department of Motor Vehicles, 2009).

2. Performance and Capabilities (2009 GEM Models)

There are currently six LSV models manufactured by GEM with the capability to transport people and cargo. Models e2, e4, and e6 are specifically designed to transport people, ranging from two to six passengers. Model e2 has the capability to transport two people, model e4 has the capability to transport four people, and model e6 has the ability to transport six passengers. Personnel and cargo transportation can be accomplished with GEM models eS, eL, and eLXD. Model S is the short cargo bed, model eL is the long cargo bed, and model eLXD is the extended cargo bed. The availability of a variety of personnel and cargo models allows GEM customers to customize each LSV to their individual requirements (Global Electric Motorcars, 2008).

3. Range and Cargo Capacity

An LSV has a range between 30–40 miles per charge with a top speed of 25 mph. This capability makes the LSV an optimal choice to transport people and cargo around communities, factories, and military installations where speed limits are below 35 mph. GEM models designed for the movement of cargo have varying capacities and a maximum capacity of 1,100 lbs in the eLXD edition. Appendix B illlustrates the specifications, dimensions, and cargo capacity of the six models manufactured in 2009 by GEM (Global Electric Motorcars, 2008).

a. Components

Since an LSV is an all-electric vehicle, the engine components are different from an internal combustion engine (ICE). The components that enable the operation of an electric LSV are the batteries, controller, motor, differential, and two half shafts. These components are listed below in order of operation and a basic description of their function is extracted from the GEM *Service Manual* and *Product Training Guide*. Appendix C provides a picture of LSV components.

- Batteries: Power the controller (Global Electric Motors, 2002, p. 3–2)
- Controller: The "brains" of the LSV, responsible for converting battery power into driving power for the motor (Global Electric Motors, 2002, p. 5–19)
- Motor: Controlled by the operator with the accelerator pedal (Global Electric Motors, 2002, p. 3–2)
- Differential/Half Shafts: The motor is connected to the differential, and the differential is connected to the half shafts. Power is transferred from the motor to the differential and from the half shafts to the front wheels of the LSV (Global Electric Motorcars, 2008, p. 17)

b. Batteries and Charging

LSVs require between six and nine 12-volt batteries of either lead-acid or maintenance-free gel batteries. LSVs operate on a 72-volt battery system, but the model of LSV purchased determines the number of batteries required (Global Electric Motorcars, 2008). Lead-acid batteries require monthly watering and maintenance while gel batteries require no miantenance. According to a study conducted by the Idaho National Laboratory, the lifecycle cost for LSV batteries is challeging to calculate, and the study estimates that six lead-acid batteries will cost about $600 and that six gel batteries are roughly $1,000 (Brayer et al., 2006).

Charging GEM LSVs is accomplished with the onboard 12-amp, 72-volt charger. The charging can be accomplished by plugging the LSV into a 110-volt outlet or into a 15-amp A/C outlet. It can also be done with an LSV-100 fast charger. Charging an LSV with a 110v outlet will take approximatly six to eight hours to recharge six batteries.

An LSV-100 can be purchased from GEM and is configured into the electrical grid with a 208 VAC/3-Phase, 50Amp breaker. The LSV-100 can recharge six batteries to 80% capacity within 30 minutes for 2005 and newer models that are equiped with the LSV-100 receptical kit (Global Electric Motorcars, 2008).

c. Warranty and Maintenance

A GEM LSV warranty is bumper-to-bumper for the first 12 months of ownership. The warranty includes 24-hour roadside assistance, tire coverage, and battery coverage. GEM also offers an extended 24-month warranty for an additional cost (Global Electric Motorcars, 2008, p. 26).

According to a study conducted by the Idaho National Laboratory, maintenance costs are driven by the following factors (Brayer et al., 2006, p. 32).

- Vehicle manufacturer
- Vehicle mission
- Charging infrastructure availability
- Owner diligence in performing preventaive maintenance

The Idaho National Laboratory study concluded that an LSV that is not operated frequently will experience more battery maintenance issues then fleets operating a fast charger, LSV-100. The fast charge conditions extended battery lives to over three years. The issues listed below are major maintenance issues identified in the Idaho National Laboratory study for LSVs (Brayer et al., 2006, p. 33).

- Battery maintenance
- Charge failures
- DC-DC converters
- Chargers
- Controllers

The most serious maintenance issue is the failure of controllers and charges due to the expense incurred to replace these parts. The study from the Idaho National Laboratory concluded that failure of the controller or charger usually results in scrapping the LSV (Brayer et al., 2006).

B. ELECTRIC VEHICLE

The success of the LSV, demand for increased driving range, and desire to travel at speeds greater than twenty-five miles per hour has influenced the development and manufacturing of PEVs. PEV costs remain higher than traditional ICE vehicles. However, as demand increases costs are expected to fall with economies of scale.

1. History

In the late 1800s, the most common mode of transportation was horseback. Electricity was adapted to transportation by the end of the century; the excitement and hope for revolutionary change was immense. Kirsch (2000) discusses two engineers, Henry Morris and Pedro Salom, who used financial support from the Electric Storage Battery Company to introduce an electric cab and carriage service known as the Electric Vehicle Company (EVC) in 1897. By 1899, the EVC—operating from the original vision of its founding engineers—merged with the Motor Carriage division of the Pope Manufacturing Company (Kirsch, 2000).

The EVC grew to become the largest vehicle manufacturer and operator of motor vehicles in the United States (Kirsch, 2000). With the financial support of William C. Whitney, a politically and financially connected transportation magnate, the EVC had the resources to execute a strategy for success (Kirsch, 2000).

By 1912, most electric cabs, buses, and sightseeing coaches ceased operations and, ultimately, the EVC failed. Kirsch (2000) offers several contributing factors to the demise of the EVC and concludes that "despite its extensive networks of suppliers, employees, and customers," the EVC was "unable to create and sustain a working, integrated technology system capable of delivering affordable electric transportation service" (p. 31). The EVC failed to understand fully the needs and wants of the customer. As Kirsch (2000) describes it, "selling service versus selling automobiles first established the principle that mechanized road vehicles could provide useful service beyond mere entertainment" (p. 32).

2. Resurgence

In 1996, General Motors (GM) introduced the EV1 electric car. The EV1 was the first modern production electric vehicle from a major automobile manufacturer in nearly a century. The idea for the EV1 originated from the GM Chief Executive Officer, Roger Smith, who served from 1981–1990. He enhanced his knowledge of electric vehicle capabilities by studying the Sunraycer, a record-breaking racecar. The Sunraycer was a solar-electric vehicle built to compete in the 1987 World Solar Challenge, a solar-powered car race in Australia. GM executed design and production of the EV1 in secrecy and away from the saturated automobile manufacturing town of Detroit, Michigan. GM's fiercest competitors were at least two or three years behind in bringing a similar product to market (Paine, 2006).

Today, the electric vehicle industry is a thriving, emerging market. Porter (1980) describes an emerging market as:

> newly formed or re-formed industries that have been created by technological innovations, shifts in relative cost relationships, emergence of new customer needs, or other economic and sociological changes that elevate a new product or service to the level of a potentially viable business opportunity. (p. 215)

Previous barriers, such as absence of infrastructure, customer confusion, regulatory approval, and high costs, are gradually diminishing. This is based, in part, on a depleting global supply of fossil fuel, unsatisfied demand, changing consumer tastes, and niche markets. In the long run, PEV constraints for mass production will largely be a function of cost and range tradeoffs (Heywood, 2007).

Electric vehicle consumers of today are predominately private and government fleets. New firms entering the electric vehicle market are rapidly expanding the customer base. Electric vehicle consumers are broadly categorized into four types (Cowan et al., 1996).

- Early adopters who are willing to pay a premium to buy and own electric vehicles in return for the prestige of being first
- Environmentally friendly consumers who are "green" stewards

- Budget-conscientious consumers who value price and quality
- Risk-averse consumers, the group most sensitive to uncertainty

3. Components

Critical power components are most often a large battery pack, large electric motor, and some type of transmission. The use and configuration of battery packs, motors, clutches, differentials, gears, and gearboxes are proprietary designs and come in many variations (MIT, 2008). A basic diagram of electric vehicle components is shown in Figure 1.

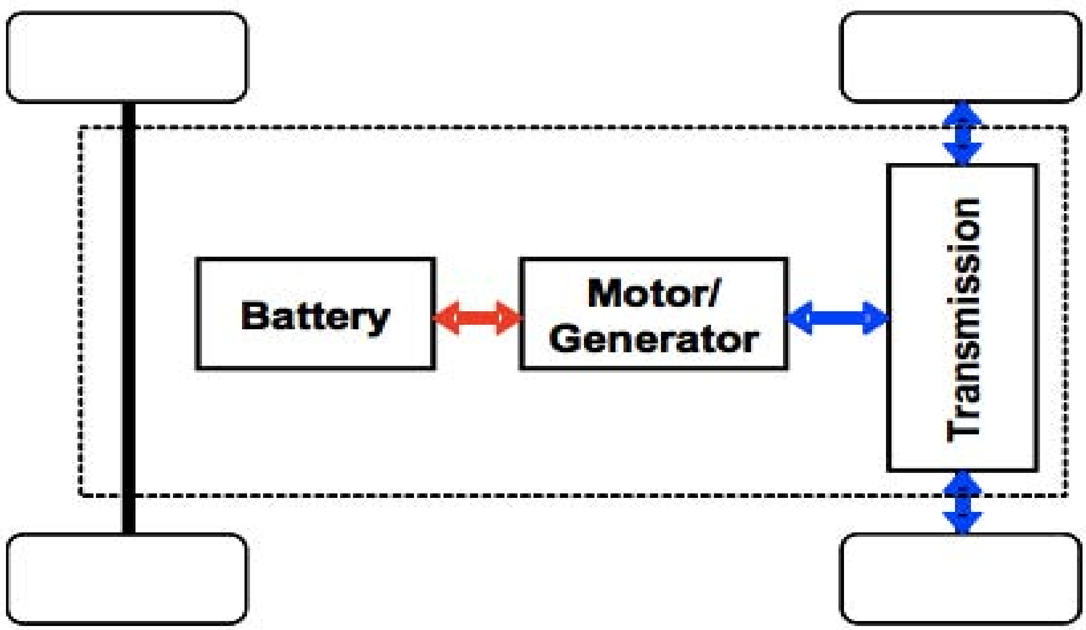

Figure 1. Diagram of Electric Vehicle Components (From: MIT, 2008)

a. Battery

PEV batteries are replenished by plugging the vehicle into a power source. Some electric vehicles have onboard chargers while others plug into a charger located outside the vehicle. Both types use electricity from the power grid (DoE, 2009a).

Poor energy storage capacity of batteries remains a key limiting factor that makes electric vehicles unprofitable for manufacturers and undesirable for consumers; however, the environment is changing. Battery technology is rapidly advancing, increasing energy storage capacity and reducing costs for many electric vehicle manufacturers (MIT, 2008).

Lithium-ion batteries are increasingly becoming the batteries of choice for many PEV manufacturers. Phoenix Motors uses a lithium-ion battery in its Sport Utility Truck (SUT) and Sports Utility Vehicle (SUV) (Phoenix, 2009a, 2009b, 2009c). See Appendix D for a complete list of Phoenix SUT and SUV specifications. Tesla Motors' initial battery design used commercially available lithium-ion batteries similar to batteries used in laptop computers (Tesla, 2009a). See Appendix E for a complete list of Tesla Model S specifications.

A potential constraint on the production of lithium batteries is the physical location of the world's lithium reserves since this location is a national security threat to the U.S. GAO-09-493 points out the uncertainty of the worldwide supply of lithium. This uncertainty presents a challenge in forecasting the supply of batteries for PEVs in the long term. Appendix F provides a list of the current leading reserves of lithium (GAO, 2009).

Despite reliance on foreign sources of lithium, the probability of developing a dependency, as seen with oil, is likely to be much smaller because lithium is highly recyclable. The current recycling culture for car batteries has a high rate of participation by auto dealerships, consumers, and parts suppliers. Lithium batteries could easily adapt to the current recycling culture (GAO, 2009).

b. Motor

The electric motor performs the task of the mechanical drive components. The motor converts electrical energy from the battery to mechanical energy that drives the wheels of the vehicle (SAIC, 2003). This is different from a gasoline-powered engine, in which the engine must build up before full torque is provided; an electric motor provides full torque at low speeds (DoE, 2009b).

c. Inverter and Controller

A motor is sometimes combined with an inverter and a controller. Inverters are devices that change power between alternating current (AC) and direct current (DC) (SAIC, 2003). Controllers are computers that use sensors to detect vehicle conditions and alter motor performance to respond to driver or system demands (DoE, 2009c).

d. Transmission

Transmission designs are especially varied. High performance electric vehicle transmissions provide manufacturers with a competitive advantage, although the competition in the industry is rapidly expanding. One of the most notable electric vehicle transmissions is the Tesla Motors Roadster. It uses a single-speed gearbox. Tesla describes the feel as the “low drag and fuel efficiency of a manual transmission with the driving ease of an automatic” (Tesla, 2009b). Just as electric vehicle transmissions differ from gasoline-powered vehicles so do some electric vehicle braking systems (MIT, 2008).

e. Brakes

Regenerative braking on electric vehicles recoups some of the energy lost during braking. Gasoline-powered vehicle brakes use friction to stop the vehicle. Excessive heat forms as the brakes rub against the discs on the wheels. The heat is lost energy. Over time, the cycle of friction and wasted energy reduces the vehicle fuel efficiency; as a result, more energy from the engine is required to replace the energy lost by braking. Regenerative braking takes some of the lost energy during braking and turns it into usable energy (DoE, 2009d). The saved energy is stored in a battery and used later to power the motor. As a driver applies the brakes, the electric motors reverse direction. The torque created by this reversal opposes the forward motion and brings the vehicle to a stop (Fuhs, 2009).

Both Phoenix Motors and Tesla Motors offer regenerative breaking in their respective electric vehicles. Tesla explains regenerative braking as “engine braking with a bonus” that “extends your charge even further, delivering higher miles-per-charge on in-town driving” (Tesla, 2009b). With the introduction of LSV and PEV, and the utilization of PV solar energy, the nation’s dependence of oil could be reduced, resulting in a strengthened national security.

C. PHOTOVOLTAIC SOLAR ELECTRIC ENERGY

The DoE has taken the lead for the United States Government in developing renewable energy, including PV solar energy. The process of converting sunlight directly into electricity is the PV process. The PV cells that conduct this transformation are made of semiconductors, such as crystalline silicon or various other thin-film materials. PV transformation can provide a wide range of power from tiny amounts for calculators to large amounts that supply the electric grid. As a solar energy technology, PV energy has numerous environmental benefits and has less of a negative impact on the environment than other power-generation technologies. As PV cells quietly generate electricity from sunlight, they produce no air pollution or hazardous waste. There is no requirement for liquid or gaseous fuels to be transported or combusted, and because its energy source, sunlight, is free and abundant, PV systems can guarantee uninhibited access to electric power. Also, as the technology base grows, the cost to produce and use PV decreases, making it more affordable and available. With regard to national security, PV frees the U.S. from the uncertainties surrounding energy supplies from politically volatile regions (DoE, 2003).

Individual PV cells are electricity-producing devices made of semiconductor materials. PV cells come in many sizes and shapes, from smaller than a postage stamp to several inches across. They are often connected together to form PV modules that may be up to several feet long and a few feet wide. Modules, in turn, can be combined and connected to form PV arrays of different sizes and power output (DoE, 2003).

1. History

Edmond Becquerel revealed the basic process of using sunlight to produce an electric current in a solid material in 1839. It took science more than a century to truly understand this process. They eventually learned that the PV effect caused certain materials to convert light energy into electrical energy at the atomic level. The benefits of PV solar energy are now being realized after a century and a half (Lenardic, 2007).

In the 1990s, the technology in PV started improving the efficiency of the systems up to 20 percent with silicon cells. Large firms, such as BP Solar International and United Solar Systems Corporation, become front-runners in the development of PV solar panels. The United States Government and the DoE enhanced their involvement in the PV development with the establishment of National Renewable Energy Laboratories (NREL). The turn of the century has brought continued PV technology growth with PV solar-powered planes developed by NASA and larger systems producing more PV solar power (Lenardic, 2007).

2. The Photoelectric Effect

The photoelectric effect is the basic physical process by which a PV cell converts sunlight into electricity. When light shines on a PV cell, it may be reflected, absorbed, or passed right through. The energy of the absorbed light is transferred to electrons in the atoms of the PV cell. With their newfound energy, these electrons escape from their normal positions in the atoms of the semiconductor PV material and become part of the electrical flow, or current, in an electrical circuit. A special electrical property of the PV cell is its built-in electric field, which provides the force, or voltage, needed to drive the current through an external load, such as a light bulb (DoE, 2003).

3. Systems

By themselves, modules, or arrays, do not represent an entire PV system. Modules are placed on structures that point them toward the sun. Components take the direct-current (DC) electricity produced by modules and convert it to alternate-current (AC)

electricity. All these items are referred to as the balance of system (BOS) components. Combining modules with the BOS components creates an entire PV system. This system usually includes everything necessary to meet a particular energy demand, such as powering a water pump or the appliances and lights in a home. If the PV system is large enough, the electrical requirements of an entire community can be supplied. PV systems can be classified into two general categories: flat-panel systems and concentrator systems (DoE, 2003).

4. Components

The functional and operational requirement determines which components the system will include. It may include major components, such as DC-AC power inverter, battery bank, system and battery controller, auxiliary energy sources, and, sometimes, the specified electrical loads appliances (Solar Direct, 2008). The following component descriptions were paraphrased from the Solar Direct Web site (2008).

a. Modules

PV Modules are comprised of several PV cells and convert sunlight instantly into direct-current electric power.

b. Inverter

Inverters convert the direct-current power into standard alternate-current power for use in the home and for synchronizing with utility power whenever the electrical grid is distributing electricity.

c. Batteries

Batteries store energy when there is excess coming in and distribute it back out when there is a demand. The solar PV modules continue to recharge the batteries each day to maintain battery charge.

d. Utility Meter

Utility meters distribute utility power automatically to provide power at night and during the day when the demand exceeds the solar electric power production. The utility meter actually spins backwards when solar power production exceeds house demand and some electric companies will credit excess-produced electricity against future utility bills.

e. Charge Controller

The charge controller prevents the battery from overcharging and prolongs the battery life of the PV system. In addition, there is an assortment of system hardware including wiring, over current, surge protection, disconnect devices, and other power processing equipment that reduces overcharging.

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III. METHODOLOGY

This project analyzes the utilization of LSVs, PEVs, and PV solar energy at MCLB Barstow. It has two major components: first is to determine feasibility for replacing ICE vehicles with LSVs and PEVs and the second is to identify PV solar energy capacity required. The commercial vehicle requirements at MCLB Barstow are determined by different daily mission variables. First, our study examined these variables to determine the feasibility of replacing the commercial vehicle fleet of ICE vehicles with LSVs and PEVs. After identifying ICE vehicle replacements, we estimated cost for replacing identified vehicles when the vehicle leases expired. Second, we determined the amount of PV solar energy required for recharging the LSV and PEV fleets on the Nebo and Yermo Annexes. Last, we calculated the cost associated with a PV system capable of recharging the LSV and PEV fleets. The methodology is depicted in Figure 2.

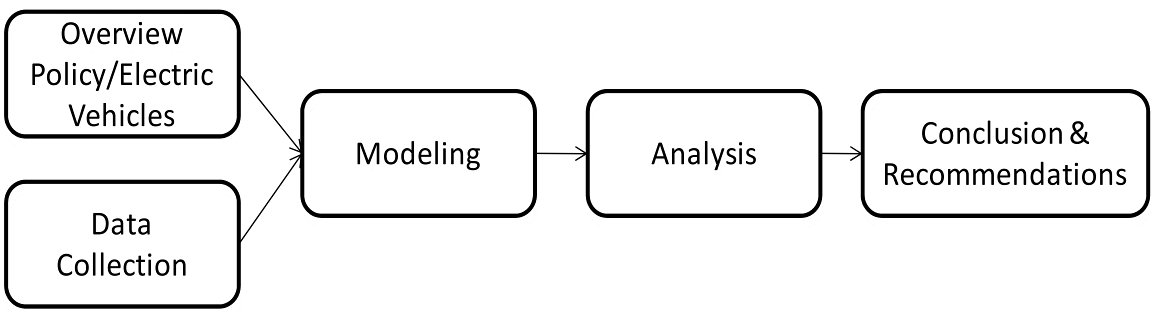

Figure 2. Methodology

A. OVERVIEW OF POLICY AND ELECTRIC VEHICLE CAPABILITIES

We first reviewed legislation impacting Federal Fleets and literature on LSVs, PEVs, and PV solar energy. This information provided the project boundaries. Second, we researched the history, current technologies, and components of the LSV and PEV. This research brought to our attention the advancements taking place in electric vehicles

and the battery systems that power these vehicles. In this research, we focus on three specific types of electric vehicles for the potential replacement of MCLB Barstow's ICE vehicles.

- A Low-speed Vehicle (LSV) made by Global Electric Motors
- An SUV and SUT (PEV) made by Phoenix Motor Company
- A Model S (PEV) made by Tesla Motor Company

Specifications for these vehicles are detailed in Appendices B, D, and E. Considerations that the project examined for recommending an alternative vehicle for an ICE vehicle currently in the MCLB Barstow Federal Fleet are listed below.

- Procurement
- Maximum speed
- Vehicle's range
- Cargo capacity
- Passenger capacity

The third area of focus is PV solar electricity. The project concentrates on how the photoelectric system works and the components that are included in the design. Also included in the research are the different sizes of PV systems available for installation on MCLB Barstow. The systems we researched included smaller, self-contained, and off-the-grid units compared to systems that could be mounted on top of a warehouse or arranged in an open field and tied to the electric grid. After discussions with the Instillations and Logistics personnel on MCLB Barstow, we concluded that one large system tied to the grid at each annex would be the most cost-effective route to pursue.

B. DATA COLLECTION

To begin the data collection for the analysis of optimizing the number of LSVs and PEVs on MCLB Barstow, we held a telephone conference with the MCLB Barstow Federal Fleet Manager and the Instillations and Logistics Manager to arrange a site visit. The field trip facilitated an understanding of the unique requirements and mission of the Federal Fleet at the base. Since the vehicles are not located in one central location, we visited all of the locations of ICE vehicles and LSVs on the Yermo and the Nebo

Annexes. We recorded the quantities and types of vehicles for every location. We completed the collection of essential data for analysis; this included the current number of fuel-powered vehicles (gasoline, ethanol, compressed natural gas, and diesel) and LSVs and the average miles per month per vehicle from the Federal Fleet Manager.

We completed a second trip to MCLB Barstow to collect data from individual shop managers responsible for ICE vehicles or LSVs. During data collection meetings, the main topic of discussion was the details of how individual shops utilized each vehicle. Questions used to collect the data are in Appendix G.

C. ASSUMPTIONS

Based on our discussions with MCLB Barstow manager and the available data we made the following assumptions.

- ICE vehicles would be replaced once their GSA lease expired
- Sufficient capacity in the PV solar systems to cover the planned future electric vehicle fleet would be purchased up front
- MCLB Barstow would pay the Manufacturer’s Suggested Retail Price for the GEM LSVs, Phoenix SUT and SUV, and the Tesla Model S
- Lifecycle cost could not be accurately calculated due to the immaturity of the technology
- Calculation of charge time would be based off of 120v electricity
- Phoenix Motors and Tesla Motors would begin production as scheduled
- LSVs and PEVs would be purchased (not leased) by the USMC.
- USMC would not qualify for the federal rebates on AFVs
- Charging of the LSVs and PEVs would occur nightly
- Data collected would correctly represent mission and mileage requirements only

D. MODELING AND ANALYSIS

In the modeling and analysis phase, we organized the data to determine the fuel-powered vehicle that could be replaced by an electric substitute, such as a GEM, or Phoenix Motor, or a Tesla electric vehicle. To accomplish this, we used information

provided on the leasing manifest that included all of the fuel-powered vehicles maintained at MCLB Barstow and the mileage data maintained by the Federal Fleet Manager. This allowed the analysis to include the actual mileage driven by an individual vehicle over the previous five months and recommend dates for acquisition of replacement vehicles.

Once we constructed the Replacement Vehicle Model, we inputted the data collected from the Federal Fleet Manager and individual shop managers to calculate if replacement LSVs or PEVs were suitable. The next phase of the analysis was to determine the total number of LSVs and PEVs in MCLB Barstow's Federal Fleet and on which annex the vehicles were going to be primarily located. This analysis allowed for a second set of calculations that determined the amount of electricity required to charge the existing and replacement LSVs and PEVs completely. With the Photovoltaic Solar Energy Model, we calculated the size of the PV solar energy system required. Once we determined the number of electric vehicles, we identified their primary locations and estimated the amount of PV solar energy necessary, which allowed us to calculate the total cost of implementing our strategy with the Present Value Model.

IV. DATA ANALYSIS

The data analysis for this project involved development of three models. The first model developed was the Replacement Vehicle Model (RVM) to determine the number of ICE in the MCLB Barstow federal fleet suitable for replacement with LSVs or PEVs. The second model, the Present Value Model (PVM), was developed to generate a cost estimate for replacing the number of vehicles generated in the RVM model. This model considers the replacement year for each ICE vehicle and then calculates the present value of money. The third model, the PV Solar Energy Model (PVSEM), was developed to generate a cost estimate for PV solar energy required to recharge the vehicles from the RVM model and the existing LSV in MCLB Barstow's Federal Fleet.

A. REPLACEMENT VEHICLE MODEL

RVM determined the number of ICE vehicles in MCLB Barstow's Federal Fleet that can be replaced with LSVs and PEVs. This was accomplished by creating a model that considered the 118 ICE vehicles from MCLB Barstow's Federal Fleet identified for the project. Daily ICE vehicle requirements are the input data to RVM. The output of the RVM is whether there is a replacement for the fleet vehicle and if there is then the recommended LSV or PEV. Table 1 displays the 45 ICE vehicles the RVM determined to be feasible of being replaced with LSVs or PEVs.

Inputs																
Equipment ID	**Year**	**Model Name**	**Annex**	**μ**	**90 % x**	**≤ 30 mls/day**	**≤ 130 mls/day**	**90% on one annex**	**90% in local area**	**Cargo ≤ 1000 lbs.**	**Cargo bed used**	**≤ 2 pass**	**≤ 4 pass**	**≤ 5 pass**	**≤ 6 pass**	**CO Veh**
G42-45849	2001	P/U F150	Nebo	11	15	1	0	0	1	1	1	0	0	1	0	0
G43-22274	2002	Van G2500	Nebo	12	17	1	0	0	1	1	0	0	0	1	0	0
G41-72772	2003	S10	Nebo	5	8	1	0	0	1	1	1	0	0	1	0	0
G42-52983	2004	P/U 1500	Yermo	11	15	1	0	0	1	1	1	0	0	1	0	0
G10-1654B	2005	Stratus	Nebo	17	22	1	0	0	1	1	0	0	0	1	0	0
G10-1543B	2005	Stratus	Nebo	5	8	1	0	0	1	1	0	0	0	1	0	0
G10-1547B	2005	Stratus	Yermo	15	20	1	0	0	1	1	0	0	0	1	0	0
G41-0870A	2005	Colorado	Nebo	12	17	1	0	0	1	1	1	0	0	1	0	0
G41-0871A	2005	Colorado	Nebo	8	12	1	0	0	1	1	1	0	0	1	0	0
G42-0299B	2005	Van G2300	Yermo	3	5	1	0	0	1	1	1	0	0	1	0	0
G62-0457B	2005	Tahoe	Nebo	13	18	1	0	0	1	1	0	0	0	0	1	1
G41-2269D	2006	Colorado	Nebo	6	9	1	0	0	1	1	0	0	0	1	0	0
G42-1089D	2006	Van E150	Yermo	12	17	1	0	0	1	1	1	0	0	1	0	0
G41-2268D	2006	Minivan	Yermo	3	5	1	0	0	1	1	0	0	0	0	1	1
G41-2270D	2006	Colorado	Yermo	14	19	1	0	0	1	1	1	0	0	1	0	0
G13-0206A	2007	Civic	Nebo	4	7	1	0	0	1	1	0	0	0	1	0	0
G42-0853F	2007	1500	Yermo	13	18	1	0	0	1	1	1	0	0	1	0	0
G61-1109D	2007	Ranger 4x4	Yermo	16	21	1	0	0	1	1	1	0	0	1	0	0
G41-1469F	2007	Ranger	Nebo	7	10	1	0	0	1	1	1	0	0	1	0	0
G41-1481F	2007	Ranger	Nebo	11	15	1	0	0	1	1	1	0	0	1	0	0
G10-8505D	2007	Malibu	Nebo	9	13	1	0	0	1	1	0	0	0	1	0	0
G13-0209A	2007	Civic	Nebo	7	10	1	0	0	1	1	0	0	0	1	0	0
G13-19272	2007	Civic	Nebo	9	13	1	0	0	1	1	0	0	0	1	0	0
G41-1477F	2007	Ranger	Nebo	8	12	1	0	0	1	1	1	0	0	1	0	0
G41-1479F	2007	Ranger	Nebo	16	21	1	0	0	1	1	1	0	0	1	0	0
G13-19271	2007	Civic	Nebo	7	10	1	0	1	0	1	0	0	1	0	0	0
G41-1476F	2007	Ranger	Nebo	10	14	1	0	0	1	1	1	0	0	1	0	0
G41-1482F	2007	Ranger	Nebo	4	7	1	0	1	0	1	1	1	0	0	0	0
G41-1471F	2007	Ranger	Yermo	15	20	1	0	0	1	1	1	0	0	1	0	0
G41-1480F	2007	Ranger	Yermo	7	10	1	0	0	1	1	1	0	0	1	0	0
G41-1470F	2007	Ranger	Yermo	3	5	1	0	0	1	1	1	0	0	1	0	0
G41-1472F	2007	Ranger	Yermo	32	39	0	1	0	1	1	1	0	0	1	0	0
G41-1473F	2007	Ranger	Nebo	17	22	1	0	0	1	1	1	0	0	1	0	0
G41-1475F	2007	Ranger	Nebo	16	21	1	0	0	1	1	1	0	0	1	0	0
G13-0202A	2007	Civic	Nebo	51	60	0	1	0	1	1	0	0	0	1	0	0
G41-1468F	2007	Liberty	Nebo	10	14	1	0	0	1	1	0	0	0	1	0	0
G43-1442F	2007	Van E150	Yermo	7	10	1	0	0	1	1	1	0	0	1	0	0
G41-0526G	2008	Colorado	Nebo	5	8	1	0	0	1	1	1	0	0	1	0	0
G41-0514G	2008	Minivan	Nebo	10	14	1	0	0	1	1	0	0	0	1	0	0
G41-0512G	2008	Minivan	Nebo	9	13	1	0	1	0	1	0	0	0	0	1	0
G41-0528G	2008	Colorado	Yermo	11	15	1	0	0	1	1	1	0	0	1	0	0
G41-0523G	2008	Colorado	Nebo	3	5	1	0	1	0	1	1	1	0	0	0	0
G41-0524G	2008	Colorado	Nebo	29	36	0	1	0	1	1	1	0	0	1	0	0
G41-0525G	2008	Colorado	Nebo	14	19	1	0	0	1	1	1	0	0	1	0	0
G41-0527G	2008	Colorado	Yermo	21	27	1	0	0	1	1	1	0	0	1	0	0

Table 1. Replacement Vehicle Model Inputs

The data inputs to RVM, columns of Table 1 are explained as follows.

1. Inputs

- Equipment Identification (Equipment ID): Sourced from the MCLB Barstow's Federal Fleet Manager from the vehicle-leasing manifest. This number is a specific serial number unique to each vehicle in MCLB Barstow's Federal Fleet.
- Year: Sourced from the MCLB Barstow Federal Fleet manager off the vehicle-leasing manifest. The year is the production date for the individual vehicle.
- Model Name: Sourced from the MCLB Barstow Federal Fleet manager off the vehicle-leasing manifest. The model name is the specific model and type of individual vehicle.
- Annex: Collected from the individual vehicle section managers on the Nebo and Yermo Annexes. This information provides which annex the vehicle is primarily located.
- Mean (μ): Sourced from five months of data (November 2008–March 2009), and collected by the Federal Fleet manager. This information provides us the average daily mileage of the individual vehicles.
- Protection Factor(90% x): Calculated using the Poisson distribution at a 90% protection level, meaning the daily miles driven will be under the number calculated 90 % of the time.
- Less than or equal to 30 miles driven per day (<= 30 mls/day): This column was given a one if the daily miles driven in the 90% x column was less than or equal to 30 and a zero if higher than 30. Excel formula: [=IF(μ<=30,1,0)]
- Less than or equal to 130 miles driven per day (<=130 mls/day): This column was given a one if the daily miles driven in the 90% x column was greater than 30 and less than or equal to 130, and a zero if higher than 130. Excel formula: [=IF(AND(μ>30, μ<=130),1,0)]
- 90% of travel conducted on one annex (90% on one annex): Collected from the section managers during the data collection meetings. This column was given a one if the vehicle was driven on its primary annex more than 90% of the time, and a zero if not.
- 90% of travel conducted in the local area (90% in local area): Collected from the section managers during the data collection meetings. This column was given a one if the vehicle was driven in the local area more than 90% of the time, and a zero if not.

- Cargo is less than 10,000 lbs: Collected from the section managers during the data collection meetings. This column was given a one if the average cargo hauled was under 1,000 pounds, and a zero if not.
- Cargo bed used: Collected from the section managers during the data collection meetings. This column was given a one if the vehicles cargo bed was used to haul items, and a zero if not.
- Less than or equal to two passengers (<= 2 pass): Collected from the MCLB Barstow Federal Fleet manager and verified by the section managers. This column was given a one if the number of passengers is less than or equal to two, and a zero if greater than two.
- Less than or equal to four passengers (<= 4 pass): Collected from the MCLB Barstow Federal Fleet manager and verified by the section managers. This column was given a one if the number of passengers is less than or equal to four and greater than two, and a zero if greater than four.
- Less than or equal to five passengers (<= 5 pass): Collected from the MCLB Barstow Federal Fleet manager and verified by the section managers. This column was given a one if the number of passengers is less than or equal to five and greater than four, and a zero if greater than five.
- Less than or equal to six passengers (<= 6 pass): Collected from the MCLB Barstow Federal Fleet manager and verified by the section managers. This column was given a one if the number of passengers was less than or equal to six and greater than five, and a zero if greater than six.
- Commanding Officer's Vehicle (CO Veh): Collected from the MCLB Barstow Federal Fleet manager and verified by the section managers. This column was given a one if the vehicle is the commanding officer's vehicle, and a zero if not.

The input data in this model allows the output formulas in the excel spreadsheet to determine if there is a suitable replacement for the ICE vehicle. If there is a suitable replacement then a specific GEM, Phoenix, or Tesla vehicle is identified. Table 2 describes the output parameters in the RVM columns.

2. Outputs

- Replacement Year (Repl. Year): Calculated by adding six years to the manufactured year of the individual vehicle. Excel formula (= Year + 6)
- No Replacement Vehicle (No Repl.): Identified if there was no suitable LSV or PEV replacement. This column was given a one if the vehicle was driven over 130 miles, driven outside the local area more than 10% of the

time, or carried cargo weighing over 1000 pounds and given a zero if all of the parameters were met. Excel formula [=IF(OR(<= 30 mls/day+ <=130 mls/day = 0, 90% on one annex + 90% in local area = 0, Cargo < 1000 lbs = 0), 1, 0)]

- Global Electric Motors e2 (GEM e2): Identified if the suitable replacement vehicle was the GEM e2. This column was given a one if the vehicle was driven less than 30 miles a day, driven on one annex, carried cargo less than 1000 pounds, but not in need of a cargo bed, and had less than or equal to two passengers. Excel formula [=IF(AND(<= 30 mls/day + 90% on one annex + Cargo <=1000 lbs. + <=2 Pass = 4, Cargo bed used = 0), 1, 0)]

- Global Electric Motors e4 (GEM e4): Identified if the suitable replacement vehicle was the GEM e4. This column was given a one if the vehicle was driven less than 30 miles a day, driven on one annex, carried cargo less than 1000 pounds and had less than or equal to four, but more than 2 passengers. Excel formula [=IF(<= 30 mls/day + 90% on one annex + Cargo <=1000 lbs. + <=4 Pass = 4, 1, 0)]

- Global Electric Motors e6 (GEM e6): Identified if the suitable replacement vehicle was the GEM e6. This column was given a one if the vehicle was driven less than 30 miles a day, driven on one annex, carried cargo less than 1000 pounds and had less than or equal to 6, but more than 4 passengers. Excel formula [=IF(<= 30 mls/day + 90% on one annex + Cargo <=1000 lbs. + <=6 Pass = 4, 1, 0)]

- Global Electric Motors eL (GEM eL): Identified if the suitable replacement vehicle was the GEM eL. This column was given a one if the vehicle was driven less than 30 miles a day, driven on one annex, carried cargo less than 1000 pounds and in need of a cargo bed, and had less than or equal to two passengers. Excel formula [=IF(<= 30 mls/day + 90% on one annex + Cargo <=1000 lbs. + <=2 Pass + Cargo bed used = 5, 1, 0)]

- Phoenix Motor Company Sports Utility Truck (Phon. SUT): Identified if the suitable replacement vehicle was the Phoenix SUT. This column was given a one if the vehicle was driven less than 130 miles a day, driven in the local area, carried less than 1000 pounds and in need of a cargo bed, and had less than or equal to five passengers. Excel formula [=IF(OR(<=130 mls/day =1, 90% in local area =1) * AND(Cargo <= 1000 lbs. = 1, Cargo bed used =1, <=5 Pass =1), 1, 0)]

- Phoenix Motor Company Sports Utility Vehicle (Phon. SUV): Identified if the suitable replacement vehicle was the Phoenix SUV. This column was given a one if the vehicle was driven less than 130 miles a day, driven in the local area, carried less than 1000 pounds, but not in need of a cargo bed, and had less than or equal to five passengers. Excel formula [=IF(OR(<=130 mls/day =1, 90% in local area =1) * AND(Cargo <= 1000 lbs. = 1, Cargo bed used =0, <=5 Pass =1), 1, 0)]

- Tesla Motor Company Model S (Model S): Identified if the suitable replacement vehicle was the Model S. This column was given a one if the vehicle was driven less than 130 miles a day, driven in the local area, carried less than 1000 pounds, and was designated as the commanding officers vehicle. Excel formula [=IF(AND(<=30 mls/day + <130 mls/day >=1, 90% on one annex +90% in local area >= 1, Cargo <= 1000 lbs. =1, CO veh =1), 1, 0)]

The following table provides the outputs from the RVM.

Inputs	Outputs								
Equipment ID	Repl. Year	No Repl.	GEM e2	GEM e4	GEM e6	GEM eL	Phon SUT	Phon SUV	Model S
G42-45849	2010	0	0	0	0	0	1	0	0
G43-22274	2010	0	0	0	0	0	0	1	0
G41-72772	2010	0	0	0	0	0	1	0	0
G42-52983	2010	0	0	0	0	0	1	0	0
G10-1654B	2011	0	0	0	0	0	0	1	0
G10-1543B	2011	0	0	0	0	0	0	1	0
G10-1547B	2011	0	0	0	0	0	0	1	0
G41-0870A	2011	0	0	0	0	0	1	0	0
G41-0871A	2011	0	0	0	0	0	1	0	0
G42-0299B	2011	0	0	0	0	0	1	0	0
G62-0457B	2012	0	0	0	0	0	0	0	1
G41-2269D	2012	0	0	0	0	0	0	1	0
G42-1089D	2012	0	0	0	0	0	1	0	0
G41-2268D	2012	0	0	0	0	0	0	0	1
G41-2270D	2012	0	0	0	0	0	1	0	0
G13-0206A	2013	0	0	0	0	0	0	1	0
G42-0853F	2013	0	0	0	0	0	1	0	0
G61-1109D	2013	0	0	0	0	0	1	0	0
G41-1469F	2013	0	0	0	0	0	1	0	0
G41-1481F	2013	0	0	0	0	0	1	0	0
G10-8505D	2013	0	0	0	0	0	0	1	0
G13-0209A	2013	0	0	0	0	0	0	1	0
G13-19272	2013	0	0	0	0	0	0	1	0
G41-1477F	2013	0	0	0	0	0	1	0	0
G41-1479F	2013	0	0	0	0	0	1	0	0
G13-19271	2013	0	0	1	0	0	0	0	0
G41-1476F	2013	0	0	0	0	0	1	0	0
G41-1482F	2013	0	0	0	0	1	0	0	0
G41-1471F	2013	0	0	0	0	0	1	0	0
G41-1480F	2013	0	0	0	0	0	1	0	0
G41-1470F	2013	0	0	0	0	0	1	0	0
G41-1472F	2013	0	0	0	0	0	1	0	0
G41-1473F	2013	0	0	0	0	0	1	0	0
G41-1475F	2013	0	0	0	0	0	1	0	0
G13-0202A	2013	0	0	0	0	0	0	1	0
G41-1468F	2013	0	0	0	0	0	0	1	0
G43-1442F	2013	0	0	0	0	0	1	0	0
G41-0526G	2014	0	0	0	0	0	1	0	0
G41-0514G	2014	0	0	0	0	0	0	1	0
G41-0512G	2014	0	0	0	1	0	0	0	0
G41-0528G	2014	0	0	0	0	0	1	0	0
G41-0523G	2014	0	0	0	0	1	0	0	0
G41-0524G	2014	0	0	0	0	0	1	0	0
G41-0525G	2014	0	0	0	0	0	1	0	0
G41-0527G	2014	0	0	0	0	0	1	0	0

Table 2. Replacement Vehicle Model Outputs

3. Interpretations

The RVM outputs generated from the data inputs provided the recommended LSV and PEV replacements for ICE vehicles in MCLB Barstow's Federal Fleet. Out of the 118 ICE vehicles identified for the project, the RVM recommends replacing 45 of MCLB Barstow's ICE vehicles with either a LSV or PEV.

Figure 3 illustrates the recommended replacement year, vehicle replacement type, and total vehicle replacements by model generated from the RVM.

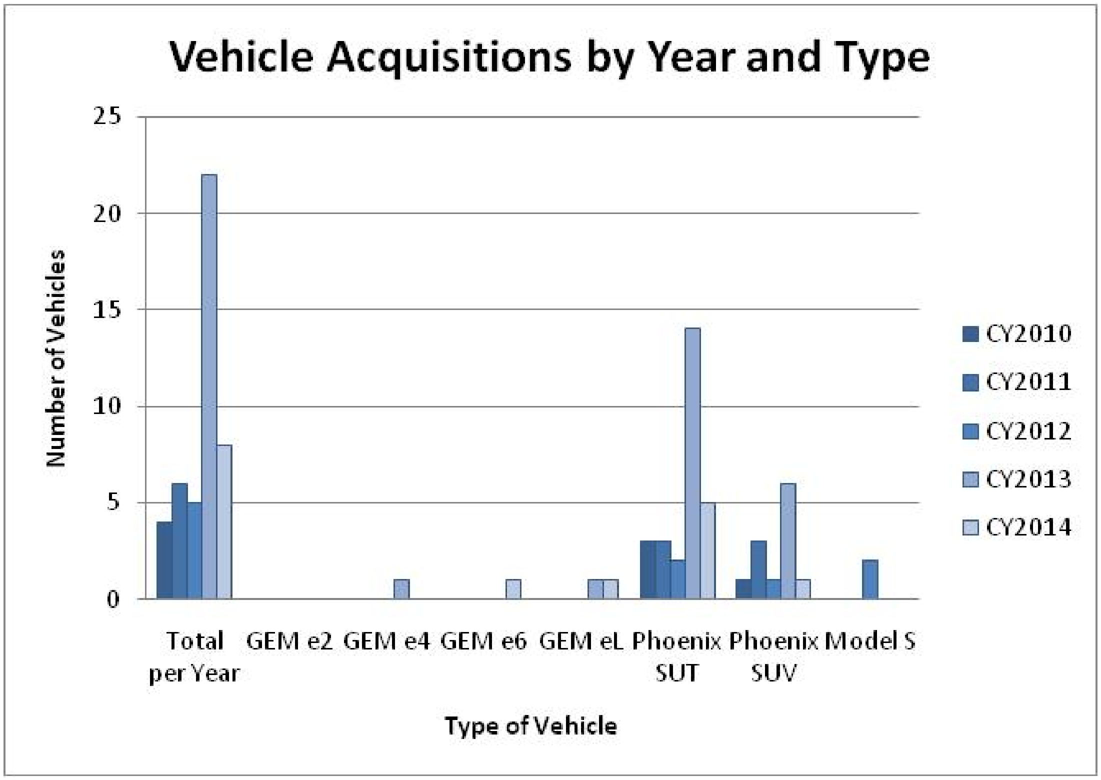

Figure 3. Vehicle Acquisitions by Year and Type

The columns in Table 3 Vehicle Model Interpretations for the RVM, are described below.

- Replacement Year 2010–2014 (2010–2014): Number of each type of vehicle to be replaced in a specific year, 2010–2014.
- Total per type of vehicle to be purchased (Total Type): this calculates the total number of each type vehicle to be purchased for the project**.**

- Total number of vehicle purchased per year (Total per Year): This calculates the total number of vehicle to be purchased in a specific year, 2010–2014.

Replacement Vehicle Model Interpretations								
Repl Year	**Total per Year**	**GEM e2**	**GEM e4**	**GEM e6**	**GEM eL**	**Phoenix SUT**	**Phoenix SUV**	**Model S**
CY2010	**4**	**0**	**0**	**0**	**0**	**3**	**1**	**0**
CY2011	**6**	**0**	**0**	**0**	**0**	**3**	**3**	**0**
CY2012	**5**	**0**	**0**	**0**	**0**	**2**	**1**	**2**
CY2013	**22**	**0**	**1**	**0**	**1**	**14**	**6**	**0**
CY2014	**8**	**0**	**0**	**1**	**1**	**5**	**1**	**0**
Total Type	**45**	**0**	**1**	**1**	**2**	**27**	**12**	**2**

Table 3. Replacement Vehicle Model Interpretations

Once the quantities of the individual types of vehicles and the years in which they would be replaced were identified, the current PVM was designed.

B. PRESENT VALUE MODEL

The Present Value Model (PVM) generates a cost estimate for replacing the number of vehicles generated in the RVM model. This model considers the replacement year for each ICE vehicle and calculates the present value of money. PVM was applied to the 45 replacement LSVs and PEV identified in the RVM. The PVM inputs include the quantity of replacement vehicles generated in the RVM and the Office of Management and Budget Circular No. A-94 (OMB Cir A-94) provides the real dollar discount rate. The output of the PVM is the actual present dollar value to acquisition the 45 total LSV and PEV identified in the RVM model over a 5-year period. Tables 4 and 5 displays the PVM utilized to determine the present dollar value required for the LSV and PEV acquisitions. The columns are described in Table 4.

1. Inputs

- The interpretations from the RVM provided the total number of vehicle to be purchased per year for the PVM.
- Real Dollar Discount Rate (Real Disc Rate (OMB Cir A-94) 2008): Referenced from the OMB, Cir A-94. This provides a discount rate for future money less inflation.
- Cost of Vehicle in Base Year 2009 (Cost (BY09 $)): Collected from the individual Manufacturer's Web sites. These Web sites provide cost of the individual types of vehicles.

Inputs (Total Number of Vehicles to be Purchased from RVM)								
Year.	# of Gem e2	# of Gem e4	# of Gem e6	# of Gem eL	# of Phoenix SUT	# of Phoenix SUV	Tesla Model S	Real Disc Rate (OMB Cir A-94) 2008
2010	0	0	0	0	3	1	0	0.00%
2011	0	0	0	0	3	3	0	2.10%
2012	0	0	0	0	2	1	2	2.10%
2013	0	1	0	1	14	6	0	2.10%
2014	0	0	1	1	5	1	0	2.20%
Cost (BY09 $)	$7,395.00	$10,295.00	$12,995.00	$10,195.00	$53,000.00	$56,000.00	$56,500.00	(Pricing from manufacturers)

Table 4. Present Value Model Inputs

The input data in this model allows the output formulas in the excel spreadsheet to determine the required funding to purchase the 45 total LSVs and PEVs in 2010 dollars The columns in Table 5, the output parameters in the PVM, are described below.

2. Outputs

- Global Electric Motors e2 (GEM e2): Calculates the present value of purchasing GEM e2 vehicles over a five-year period (2010–2014). Excel formula [=PV(Number of GEM e2 purchased in the year, number of years to purchase, number of payments made, purchase price)]
- Global Electric Motors e4 (GEM e4): Calculates the present value of purchasing GEM e4 vehicles over a five-year period (2010–2014). Excel formula [=PV(Number of GEM e4 purchased in the year, number of years to purchase, number of payments made, purchase price)]

- Global Electric Motors e6 (GEM e6): Calculates the present value of purchasing GEM e6 vehicles over a five-year period (2010–2014). Excel formula [=PV(Number of GEM e6 purchased in the year, number of years to purchase, number of payments made, purchase price)]
- Global Electric Motors eL (GEM eL): Calculates the present value of purchasing GEM eL vehicles over a five-year period (2010–2014). Excel formula [=PV(Number of GEM eL purchased in the year, number of years to purchase, number of payments made, purchase price)]
- Phoenix Motors SUT (Phon. SUT): Calculates the present value of purchasing Phon. SUT vehicles over a five-year period (2010–2014). Excel formula [=PV(Number of Phon. SUT purchased in the year, number of years to purchase, number of payments made, purchase price)]
- Phoenix Motors SUT (Phon. SUV): Calculates the present value of purchasing Phon. SUV vehicles over a five-year period (2010–2014). Excel formula [=PV(Number of Phon. SUV purchased in the year, number of years to purchase, number of payments made, purchase price)]
- Tesla Motors Model S (Tesla Model S): Calculates the present value of purchasing Tesla Model S vehicles over a five-year period (2010–2014). Excel formula [=PV(Number of Tesla Model S purchased in the year, number of years to purchase, number of payments made, purchase price)]

Outputs (Required funding to purchase 45 LSV/PEV in 2010 $)								
	Gem e2	Gem e4	Gem e6	Gem eL	Phon SUT	Phon SUV	Tesla Model S	Present Value in 2010 $
2010	$0.00	$0.00	$0.00	$0.00	$159,000.00	$56,000.00	$0.00	$215,000.00
2011	$0.00	$0.00	$0.00	$0.00	$155,729.68	$164,544.56	$0.00	$320,274.24
2012	$0.00	$0.00	$0.00	$0.00	$101,684.41	$53,720.07	$108,399.42	$263,803.90
2013	$0.00	$9,672.73	$0.00	$9,578.78	$697,150.72	$315,690.89	$0.00	$1,032,093.12
2014	$0.00	$0.00	$11,911.67	$9,345.09	$242,908.26	$51,331.56	$0.00	$315,496.59
Total	$0.00	$9,672.73	$11,911.67	$18,923.87	$1,356,473.07	$641,287.08	$108,399.42	$2,146,667.84

Table 5. Present Value Model Outputs

3. Interpretation

The PVM outputs generated from the data inputs provided the required funding to purchase 45 total LSVs and PEVs over five years to replace ICE vehicles in MCLB Barstow’s Federal Fleet. The descriptions below define the actual interpretation of the PVM outputs in Table 5, required funding to purchase 45 LSV/PEV in 2010 $.

- Total Present Value per Year (Present Value in 2010 $): Calculates the present value of purchasing vehicles over a five-year period (2010–2014). Excel formula [=SUM(discount purchase price of all vehicles bought in a year between 2010–2014)]

Over the 5-year period, the PVM calculated a present value of $2,146,668 to purchase 45 total LSVs and PEVs for MCLB Barstow's Federal Fleet.

Figure 4 illustrates the year of replacement, vehicle replacement type, and the 2010-dollar value required to purchase the vehicles.

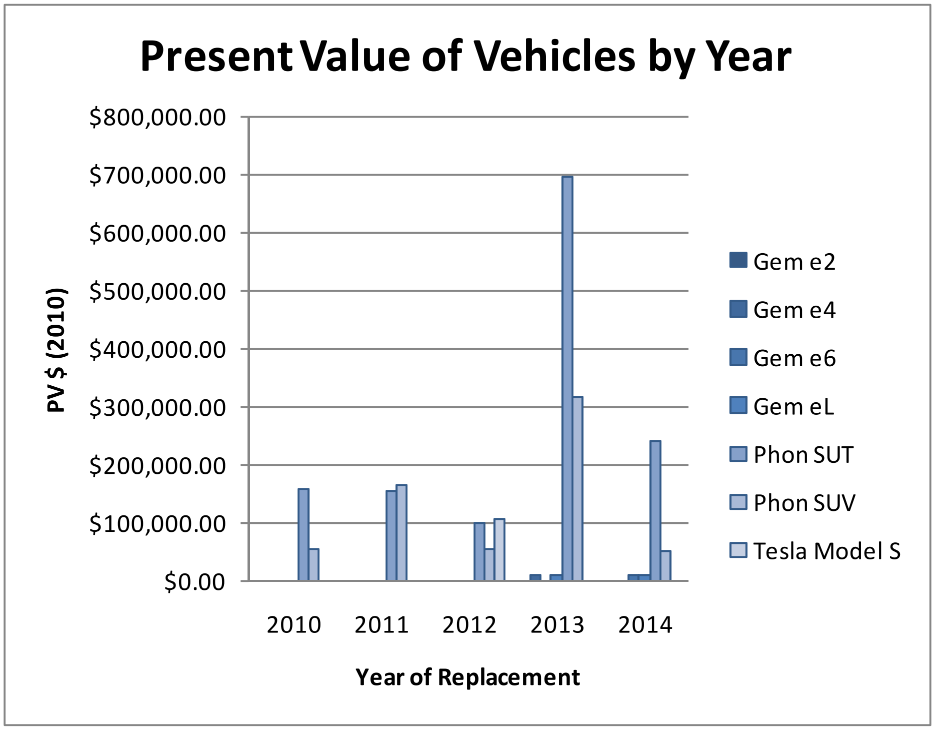

Figure 4. Present Value of Vehicles by Year

C. PHOTOVOLTAIC SOLAR ENERGY MODEL

The third model developed, PVSEM, calculates the amount of PV solar energy required to charge all of the vehicles, the amount of PV solar energy produced by three different PV systems and estimates cost for the systems to produce the PV solar energy. The PVSEM inputs included the 45 vehicles calculated from the RVM and the 113 existing LSVs from MCLB Barstow's Federal Fleet. It also included the number of

vehicles by annex, kWh required to charge individual vehicles, and charging hours required for individual vehicles. These inputs allowed the model to output the total amount of PV solar energy required and the cost of the PV solar systems. Tables 6, 7 and 8 display the PVSEM. The columns of Table 6, the input parameters used in the PVSEM, are described below.

1. Inputs

- Total LSVs and PEV Vehicles on Nebo (Total Veh on Nebo): Provided from the current LSV fleet at MCLB Barstow and the RVM.
- Total LSVs and PEV Vehicles on Yermo (Total Veh on Yermo): Provided from the current LSV fleet at MCLB Barstow and the RVM.
- Kilowatts per hour drawn from the Individual vehicle (kWh): As specified by the manufacturer and provides the amount of kW drawn per hour by the individual vehicle.
- Charging Time in Hours (Charge Time (hours)): As specified by the manufacturer and provides the amount of time to charge the individual vehicles fully.

Inputs				
	Total Veh on Nebo	Total Veh on Yermo	kWh	Charge Time (hours)
Gem e2, e4, e6, eL	18	99	1.1	8
Phon SUT, SUV	25	14	6.6	6
Tesla Model S	1	1	13.2	4

Table 6. Photovoltaic Solar Energy Model Inputs

The input data in this model allows the output formulas in the Excel spreadsheet to determine the required PV solar energy, amount of solar energy produced, and a cost estimate for a PV solar systems capable of charging all electric vehicles in MCLB Barstow's Federal Fleet.

Inputs	Outputs				
		Full charge		75% charge	
	Total kW	Total kWh (Nebo)	Total kWh (Yermo)	75% kWh (Nebo)	75% kWh (Yermo)
Gem e2, e4, e6, eL	8.8	158.4	871.2	118.8	653.4
Phon SUT, SUV	39.6	990	554.4	742.5	415.8
Tesla Model S	52.8	52.8	52.8	39.6	39.6

Table 7. Photovoltaic Solar Energy Model Outputs

The columns of Table 7, the output parameters produced in the PVSEM, are described below.

2. Outputs

- Total kilowatts used (Total kW): Calculated by multiplying the (kWh) by the (Charge Time (hours)). This provides the total kWs required to fully charge an individual vehicle. Excel formula [=(kW per hour)*(Charge Time (hours))].
- Full Charge Total kilowatts hours for the Nebo Annex (Total kWh (Nebo)): Calculated by multiplying the (Total kW) by the number of individual vehicles on the Nebo Annex. This provides the total kWs needed to charge all of the individual types of vehicle on the Nebo Annex. Excel formula [=(Total Veh on Nebo)* (Total kW)].
- Full Charge Total kilowatts hours for the Yermo Annex (Total kWh (Yermo)): Calculated by multiplying the (Total kW) by the number of individual vehicles on the Yermo Annex. This provides the total kWs needed to charge all of the individual types of vehicle on the Yermo Annex. Excel formula [=(Total Veh on Yermo)* (Total kW)].
- 75% Charge Total kilowatts hours for the Nebo Annex (75% kWh (Nebo)): Calculated by multiplying the (Total kWh (Nebo)) by 75%. This provides the total kWs needed to charge all of the individual types of vehicle on the Nebo Annex assuming that the vehicle still has 25% charge left. Excel formula [=(Total kWh (Nebo))* .75)].

- 75% Charge Total kilowatts hours for the Yermo Annex (75% kWh (Yermo)): Calculated by multiplying the (Total kWh (Yermo)) by 75%. This provides the total kWs needed to charge all of the individual types of vehicle on the Yermo Annex assuming that the vehicle still has 25% charge left. Excel formula [=(Total kWh (Yermo))* .75)].

3. Interpretation

The PVSEM outputs generated from the data inputs provided the required total monthly kWh, for Nebo and Yermo annexes, to recharge 158 vehicles to 100% or 75% of their capacity. To fully recharge 44 vehicles daily on the Nebo Annex a total of 27,628 kWh is required monthly, and to recharge 44 vehicles daily at 75% of their capacity requires 20,720 kWh monthly. Fully recharging 114 vehicles daily on the Yermo Annex requires 34,003 kWh monthly, and to recharge 114 vehicles daily at 75% of their capacity requires 25502 kWh monthly.

Figure 5 illustrates the total monthly kWh requirements for each annex when recharging all vehicles daily to 100% or 75%. The below description defines the actual interpretation of the PVSEM outputs in Table 8.

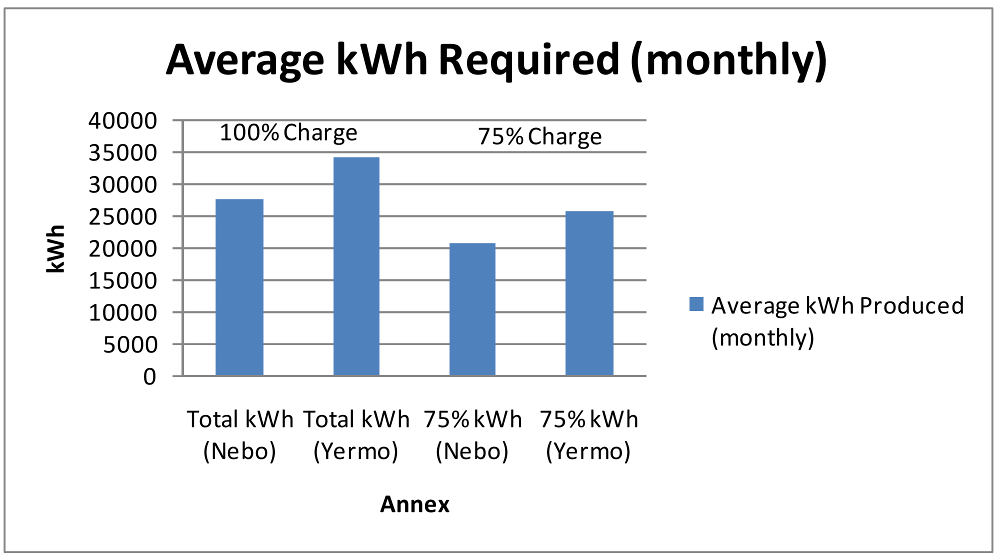

Figure 5. Average kWh Required (Monthly)

- Total kWh required monthly (Total Monthly (kWh)): Calculated by adding the total kWh required by the different types of vehicles on the annexes and multiplying that by 23 (average workdays in a month). This provides the total amount of kWh required monthly to recharge the vehicles in the fleet. Excel formula [=SUM(Total kWh (annex)) * 23)]

Table 8 illustrates the interpretations from the PVSEM.

PVSEM Interpretations				
	Full charge		75% charge	
Total kW	**Total kWh (Nebo) (Monthly)**	**Total kWh (Yermo) (Monthly)**	**75% kWh (Nebo) (Monthly)**	**75% kWh (Yermo) (Monthly)**
Total Monthly (kWh)	27627.6	34003.2	20720.7	25502.4

Table 8. Photovoltaic Solar Energy Model Interpretations

The systems that were researched for the project ranged in size of 200 kW to 300 kW. They produced a range in a range of 21682kWh–32523kWh in December to 32838kWh–49256kWh in April.

Figure 6 illustrates the average amount of kWh produced monthly by the 200 kW, 250 kW and 300 kW systems. This data was collected from the Kyocera Inc. Web site for the average kWh produced per month for the Barstow, California area. Appendix H, Average kWh Produced (monthly), details the average monthly production of the three PV solar systems and the associated cost.

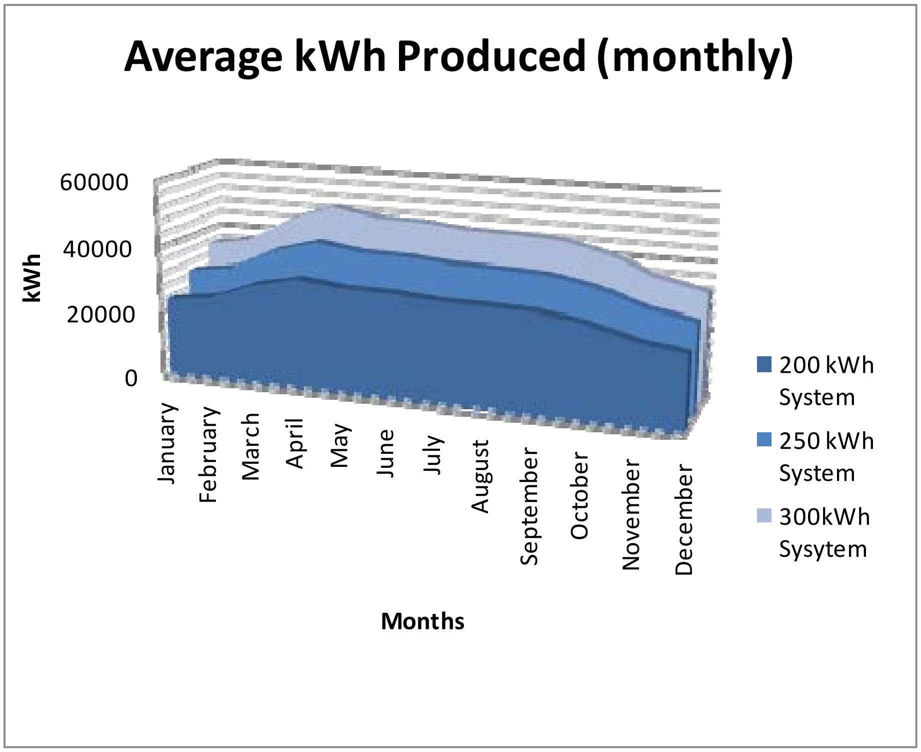

Figure 6. Average kWh Produced (Monthly)

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V. SUMMARY AND CONCLUSION

The primary goal of this research study was to estimate upfront costs associated with transitioning MCLB Barstow's Federal Fleet to LSV and PEV. In addition, the cost for PV solar energy capable of charging all electric vehicles was also estimated. To accomplish these goals, the project required collecting data from MCLB Barstow's Federal Fleet Manager, individual shop managers, and the development of three models for data analysis. First, the RVM was developed to identify the quantity of ICE vehicles in MCLB Barstow's Federal Fleet that could be replaced with a LSV or PEV. This was essential to estimate the required PV Solar energy requirements at MCLB Barstow. Second, the PVM was developed to establish a present dollar value cost estimate for the acquisition of the LSV and PEV identified in the RVM model over a 5-year period. Third, the PVSEM was developed to identify the amount of solar energy required to charge all the vehicles, to compare three different potential kW PV systems, and to generate a cost estimate for three different potential kW systems. The data collection and the three models combined allowed for a total cost estimate of the upfront costs associated with transitioning MCLB Barstow's Federal Fleet to LSVs, PEVs, and PV solar energy.

This project identified a total of 45 ICE vehicles that could be replaced. The majority of these vehicles are being replaced with Phoenix Motor Company's SUT and SUV, totaling to 39. There were also four GEM vehicles and two Tesla Motor's Model S vehicles used as replacements. The total cost of replacing these 45 vehicles over a 5-year period (as their individual leases expired) was calculated to be $2,146,668, (Table 5).

Once the number of ICE vehicles to be replaced was calculated and their primary locations were identified, the amount of PV solar energy required at the separate annexes was determined. The amount of energy required was based on a 23-work-day month and the vehicles requiring a full recharge or a 75% recharge. The requirements were

calculated to be 27628 kWh at full recharge and 20721 kWh at 75% recharge on the Nebo Annex and 34003 kWh at full recharge and 25502 kWh at 75% recharge on the Yermo Annex, (Table 8).

The requirements fell within the range of three different size PV solar systems: a 200 kW, 250 kW, and 300 kW. The 200 kW grid connected system produced on average 27973 kWh per month with a low of 21682 kWh in December and a high of 32838 kWh in April. The 250 kW grid connected system produced on average 34961 kWh per month with a low of 27102 kWh in December and a high of 41047 kWh in April. The largest, a 300 kW grid connected system produced on average 41953 kWh per month with a low of 32523 kWh in December and a high of 49256 kWh in April. The costs of these PV solar systems are $1.2 million, $1.5 million, and $1.8 million, respectively, (Appendix H).

This brought the total cost of implementing the project in the range of $4.55 million to $5.75 million, depending on the PV solar systems selected. This was calculated by adding the total cost of replacing 45 ICE vehicles and purchasing a PV system for both the Nebo and the Yermo Annexes. Table 9, Total Cost Estimates, illustrates these numbers.

Number of Vehicles	Cost of Vehicles	PV on Nebo Annex	Cost of PV	PV on Yermo Annex	Cost of PV	Total Cost
45	$2.15M	200kW	$1.2M	200kW	$1.2M	$4.55M
45	$2.15M	200kW	$1.2M	250kW	$1.5M	$4.85M
45	$2.15M	250kW	$1.5M	250kW	$1.5M	$5.15M
45	$2.15M	200kW	$1.2M	300kW	$1.8M	$5.15M
45	$2.15M	250kW	$1.5M	300kW	$1.8M	$5.45M
45	$2.15M	300kW	$1.8M	300kW	$1.8M	$5.75M

Table 9. Total Cost Estimates

We recommend that the MCLB Barstow purchase a 200 kW solar system for the Nebo Annex and a 250 kW system for the Yermo Annex, based off the data collected. The 200 kW system on the Nebo Annex will meet the 75% recharge requirements 12 months out of the year or the 100% recharge requirements eight months out of the year.

The 250kW system on the Yermo Annex will meet the 75% recharge requirements 12 months out of the year or the 100% recharge requirements eight months out of the year. With this recommendation, the cost estimate of replacing 45 ICE vehicles and these PV solar systems is $4.85 million.

A. ADDITIONAL BENEFITS

During this project, we discovered that not all electricity is created equally; electricity that is produced during the peak hours is worth more than electricity produced during non-peak hours. This project did not take into account the actual time that the electricity produced by the PV solar system was used. The study only looked at the PV solar systems that produced sufficient amounts of electricity to recharge the LSVs and PEVs. Electricity costs are based on load growth and peak demand. Electricity rates charged during the day are often much more expensive than night rates of electricity. Further study could calculate the additional benefits from implementing the recommendations of this project. For example, an installed PV system would feed directly into a maintenance facility at MCLB Barstow during the peak hours, reducing the amount of more expensive power needed from the grid, thus reducing costs. Further contribution to reducing costs could be achieved by recharging the LSVs and PEVs at night.

B. FUTURE WORK

In addition to the benefits of the 45 replacement vehicles and the PV solar energy at MCLB Barstow, there are other areas that require further investigation that could provide addition benefits for the USMC and the DOD. Some of these possible areas of research are the following.

- Effects of maximizing the excess amount of electricity produced by the Wind Turbine of the Yermo Annex
- Lifecycle Costs associated with LSV, PEV, and PV solar systems
- Benefits of centralized fast charging stations on MCLB Barstow
- Future alternative fuel infrastructure requirements in the DoD and the commercial sector

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APPENDIX A.

History of Actions and Mandates Relative to Federal Fleets, Alternative Fuel Vehicles, and Alternative Fuel Use
November 10, 2008
Prepared by the Federal Energy Management Program (FEMP)
Chronology of Events

Alternative Motor Fuels Act of 1988 (AMFA)

- **Requirements:** The first significant legislation to impose alternative fuel vehicle (AFV) requirements on federal fleets. Required fleets to acquire "the maximum number practicable" of light-duty cars and trucks that were dedicated or dual-fuel vehicles powered by alcohol fuel or natural gas.
- **Actions:** Under AMFA, Department of Energy (DOE) evaluated dual-fueled vehicles in terms of emissions, performance, operation, and maintenance.
- **Results:** Created the first markets for alternative fuel vehicles produced by the manufacturers. Initial results were limited because of the lack of available vehicles. Vehicle evaluation studies began as case studies of early installations.
- **Exemptions:** The Act required federal agencies to make alternative fuels available to the public to "the extent practicable, at locations where vehicles acquired under subsection (a) are supplied with alcohol or natural gas, alcohol or natural gas shall be offered for sale to the public." However, there were five considerations to be made before offering sales to the public. These include:
    - Whether alcohol or natural gas is commercially available for vehicles in the vicinity of such location
    - Security and safety considerations
    - Whether such sale is in accordance with applicable local, state, and federal law
    - The ease with which the public can access such location
    - The cost to the United States of such sale

Clean Air Act of 1990

- **Requirements:** Required all fleets to meet State Implementation Plan (SIP) requirements for the purchase of clean-fuel fleet vehicles under the Clean-Fuel Fleet Vehicle Program.

- **Actions:** Federal fleets started to consider the purchase of "clean-fuel" vehicles as part of the normal acquisition process. Federal fleet managers started to consider tailpipe emission characteristics in the acquisition planning for purchased vehicles—particularly in California. Federal fleet managers started to work together and with manufacturers to identify impacts and opportunities.
- **Results:** Department of Defense (DOD) started installation of compressed natural

1 42 USC 6374(c)—Availability to the Public gas refueling sites at military bases in California and was a major early adopter of natural gas vehicles. General Services Administration (GSA) started purchases of vehicles available from original equipment manufacturers that could use methanol blended fuels (M85—85% methanol and 15% gasoline).

Executive Order 12579—"Federal Energy Management"

- **Requirements:** Required the maximum number practicable of vehicles acquired by the federal fleet to be AFVs (section 11).
- **Actions:** DOE developed detailed guidance for agencies, and (along with GSA) coordinated evaluation of agency plans. DOE also provided data and training to agencies, and worked with GSA to procure vehicles, as well as providing guidance on conversion of existing vehicles. DOE and GSA tasked to coordinate agency fuel requirements to encourage development of commercial infrastructure.
- **Actions:** The Alternative Fuels Data Center (AFDC) was created in 1991 as one of DOEs first online information resource centers to make alternative fuel vehicle evaluation studies available to the public. The AFDC collected data from fleet case studies, analyzed the data, and published the results. The AFDC has expanded significantly, and continues to exist today at http://www.afdc.energy.gov.

Energy Policy Act of 1992 (EPAct 1992)

- **Requirements:** Certain percentages of federal light-duty vehicle acquisitions in metropolitan statistical areas must be AFVs. The current requirement of 75% of acquisitions became effective in 1999. EPAct 1992 also expanded the requirements for DOE to provide information and

technical resources to support the efforts of federal and other regulated fleets, and called for the establishment of voluntary efforts at the state and local level to help coordinate alternative fuel implementation.

- **Also under EPAct 1992:** Clean Cities was authorized to assist regulated fleets in meeting requirements though working with vehicle manufacturers, fuel providers, and other fleets to smooth the transition to AFVs. EPAct 1992 created mandatory requirements for state and alternative fuel provider fleets, which expanded the universe of fleets that had to incorporate AFVs, thus increasing the opportunities for AFVs to be produced and alternative fuel (AF) to be made available.

- **Actions:** In response to EPAct 1992, DOE expanded the resources available through the AFDC to include a wide range of information useful to federal and other fleets about available vehicles, fuel station locations, relevant incentives and regulations, industry resources, and success stories. Additionally, federal agencies acquired and continue to acquire various types of AFVs that used a variety of alternative fuels.

- **Results:** Federal fleets as a whole have met the acquisition requirements for several years (2007 compliance was over 170%). All individual agencies met the 75% requirement in 2007. Methanol (M85) was used in M85-capable AFVs for several years, but this type of AFV does not exist in federal fleets today. The availability of light-duty compressed natural gas (CNG), liquefied petroleum gas (LPG), and liquefied natural gas (LNG) vehicles has declined in use because original equipment manufacturers (OEMs) have ceased to produce these vehicles, with the exception of Honda's CNG Civic, in the light-duty vehicle classes that represent the preponderance of federal fleet vehicles.

Interagency Committee for Alternative Fuels and Low-Emission Vehicles (INTERFUEL) (1991)

- **Actions:** In response to the "Clean-Fuel Fleet Vehicle" program established by the Clean Air Act of 1990, federal fleet managers began to work with each other to understand the statutory requirements and collectively respond to the Environmental Protection Agency's (EPA) rulemaking process. These efforts culminated with a three-day Department of the Navy sponsored government/industry meeting. Following that meeting, federal fleet managers agreed to continue meeting with each other monthly and INTERFUEL became the umbrella forum for those discussions. Funding of INTERFUEL was by the Department of the Navy from 1991 until 1998, the United States Postal Service from 1998 to 2001, and by the DOE since 2002.

- **Results:** Federal fleet representatives and other stakeholders meet monthly to discuss topics of mutual interest. Policy implications and implementation barriers are often discussed, and working groups sometimes formed to address issues relevant to federal fleets. Members have collectively developed "draft" comments on every piece of legislation, all proposed Executive Orders, and new regulations related to the use of alternative fuels and reductions in petroleum use in federal fleets. Individual member agencies have then used the draft comments to tailor their own responses as appropriate. Outside speakers are brought into the monthly meetings to educate the members on new technologies and opportunities for fleets to reduce fuel consumption, increase alternative fuel use, and reduce vehicle emissions.

Executive Order 13031 (1996)

- **Requirements:** Required agencies to submit annual compliance reports and to advise the Office of Management and Budget (OMB) on their compliance with EPAct 1992.
- **Action:** DOE collects and publishes reports on the FEMP Web site at http://www1.eere.energy.gov/femp/about/annual_reports.html.
- **Results:** Agencies submit annual compliance reports. The need for a unified reporting system – now Federal Automotive Statistical Tool (FAST) – started with these requirements.

Energy Conservation and Reauthorization Act of 1998 (ECRA 1998)

- **Requirements:** ECRA required that federal fleets submit an annual report on compliance to Congress—this was not a requirement prior to the enactment of this legislation. Also, DOE was required to issue rulemaking to establish the biodiesel credit procedures.
- **Actions:** DOE issued rulemaking to implement the biodiesel credit procedures.
- **Results:** Amended EPAct 1992 to allow AFV acquisition credit for every 450 gallons of pure biodiesel used in diesel vehicles. In 2007, federal agencies used nearly two million gallons of pure biodiesel fuel.

Executive Order 13149 (2000)

- **Requirements:** Required agencies to comply with EPAct 1992; reduce petroleum consumption 20% by 2005, use alternative fuel in AFVs more than 50% of the time the vehicles were in operation. DOE was required to create a reporting database (FAST) and annually submit an overall federal

report to OMB (unlike ECRA, which required each agency to submit a compliance report to Congress on AFV acquisitions only) and designate a senior official to be responsible for the implementation of these requirements for each agency. Executive Order 13149 also expanded the program to include medium-duty and heavy-duty vehicles in terms of fuel reduction use. Extra EPAct credits were given to dedicated vehicles including medium-duty and heavy-duty AFVs.

- **Actions:** DOE implemented new reporting structure and analysis activities to determine agency-specific baselines, propose compliance strategies, and monitor results. Outreach and assistance efforts were expanded to help resolve barriers, link fleets to resources in Clean Cities, and leverage efforts among regulated and voluntary entities.
- **Results:** Medium-duty, heavy-duty, and dedicated AFVs earn multiple AFV acquisition credits. Federal agencies as a whole did not meet the 20% reduction requirement or the requirement to use alternative fuel the majority of the time due to limited fuel availability, conflicting policies, and data collection gaps. Results of acquisitions of higher fuel economy vehicles were mixed. Agencies have designated senior official and currently use FAST for a variety of data entry and reporting requirements.

AFDC Expansion (2004)

- **Actions:** DOE expanded the content of the AFDC beyond alternative fuels to cover the range of options useful to fleets for reducing petroleum use, including hybrid electric vehicles, higher fuel economy, reduction of vehicle miles traveled (VMT), truck idle reduction, and other measures. Online tools, such as vehicle search tools, route mappers for fuel access, and cost calculators were made available via the Web.
- **Results:** A broader range of tools and resources was available to help federal fleets meet their petroleum reduction goals. This broader perspective was also reflected in the expanded portfolio of the Clean Cities program, which provided additional educational, partnership, and local collaboration opportunities.

Energy Policy Act of 2005 (EPAct 2005)

- **Requirements:** Section 701 of EPAct 2005 requires dual-fuel AFVs to use alternative fuel 100% of the time unless the agency receives a waiver from DOE due to unavailability or unreasonable expense of the alternative fuel.

- **Actions:** DOE developed procedures and published guidance for implementing Section 701. DOE evaluates agency waiver submissions annually. DOE initiates activity to help fleets match vehicle locations with fuel availability, and to expand outreach to fuel providers about the opportunity presented by the new requirement.
- **Results:** Federal agencies submit annual waiver requests to DOE that are evaluated, and then approved or disapproved. The number of approved waivers dropped by about 7,000 AFVs from 2008 to 2009 – a decrease of about 10%.

OMB Transportation Scorecards (2005)

- **Requirements:** Agencies are required to submit planned petroleum reduction initiatives to OMB twice annually. These initiatives, along with compliance of EPAct 1992 and Executive Order 13423, are evaluated.
- **Actions:** DOE completes analysis and evaluation of agency activities to produce the scorecards that are forwarded to OMB for dissemination.
- **Results:** Federal agency results vary. Federal agency compliance with EPAct 1992 AFV acquisition requirements was universally successful in 2007, while federal agencies were less successful in always using alternative fuels in AFVs.

Executive Order 13423 (2007)

- **Requirements:** Agencies are required to reduce annual petroleum consumption 2% annually and increase non-petroleum fuel use 10% annually through the year 2015, both relative to a 2005 baseline. Agencies must acquire plug-in hybrid vehicles when they are commercially available and reasonably priced.
- **Actions:** DOE published an Executive Order 13423 guidance document.
- **Results:** Federal agencies as a whole exceeded the 10% annual alternative fuel use increase requirement for 2007, and nearly achieved the 2% annual petroleum reduction requirement by reducing petroleum consumption more than 3.9% in 2007 relative to 2005. INTERFUEL was identified as the "fleet working group" under this Executive Order by the Office of the Federal Environmental Executive.

Energy Independence and Security Act of 2007 (EISA 2007)

- **Requirements:** Language similar to Executive Order 13423 is included in EISA 2007 Section 142 (DOE is required to conduct a rulemaking to clarify). In addition, federal agencies must install a renewable fuel pump at every federal fleet-fueling center under EISA 2007 Section 246, and agencies cannot acquire light-duty motor vehicles that are not low greenhouse gas emitting vehicles (EPA has lead on this determination).
- **Actions:** DOE is conducting a rulemaking on Section 142 of EISA 2007. Federal fleets provided renewable fuel pump location data in September 2008 as a first requirement in meeting EISA 2007 Section 246 requirements.
- **Results:** Federal agencies continue to attempt to comply with Executive Order 13423 requirements and should initiate renewable fuel pump installation actions at selected agency sites.

OMB Transportation Scorecard Metric Modification (2008)

- **Requirements:** Agencies are evaluated on the reduction of waivers received annually under Section 701 of EPAct 2005.
- **Actions:** DOE determines the number of annual waiver reductions based on the number of current and previous year approved waivers.
- **Results:** Results vary. Some agencies were successful in reducing waiver requests, while others were not. The waiver process conducted in 2008 (approving/disapproving waivers for the upcoming 2009 year) was only the second year that the waiver evaluation process has been in effect.

National Defense Authorization Act of 2008 (NDAA 2008)

- The NDAA amended the Energy Policy Act of 1992 by adding several new vehicles to the definition of "alternative fueled vehicle" including:
  - A new qualified fuel cell motor vehicle (as defined in section 30B(b)(3) of the Internal Revenue Code of 1986)
  - A new advanced lean burn technology motor vehicle (as defined in section 30B(c)(3) of that Code)
  - A new qualified hybrid motor vehicle (as defined in section 30B(d)(3) of that Code)
  - Any other type of vehicle that the Administrator of the Environmental Protection Agency demonstrates to the Secretary of Energy would achieve a significant reduction in petroleum

consumption. Section 30.B of the Internal Revenue Service (IRS) Code provides definitions of each of these vehicles. EPAct 1992 AFV acquisition credits will be awarded to federal agencies for acquiring these newly defined AFVs beginning in fiscal year (FY) 2009. Agencies will be awarded one AFV acquisition credit for each qualifying vehicle acquired, regardless of weight class. In other words, light-duty, medium-duty, and heavy-duty vehicles that meet the definitions for one of these newly defined AFVs will earn one EPAct 1992 AFV acquisition credit.

Ongoing DOE Implementation Actions Pursuant to the Regulations:

EPAct 2005 Section 701 Waiver Analysis (2008)

- **Requirements:** DOE is responsible for granting AFV waivers.
- **Actions:** DOE conducted an in-depth analysis of approved federal agency waivers under Section 701 of EPAct 2005. Analysis revealed many geographical areas containing high concentrations of federal AFVs were without access to alternative fuel. DOE scheduled and hosted an Alternative Fuel Industry Forum and advised alternative fuel providers of the potential of federal fleet alternative fuel use.
- **Results:** Analysis highlighted opportunities for increased fuel infrastructure and elicited significant interest from both fleets and fuel providers.

DOE Petroleum Reduction Strategies (2008)

- **Requirements:** Internal DOE policies require the development of petroleum reduction strategies at DOE sites.
- **Actions:** DOE federal fleet team is providing technical support and on-site reviews with DOE fleets to share best practices, resolve barriers, and suggest improvements. Currently, there are no vehicles that meet this definition.
- **Results:** DOE sites are in the process of developing executable petroleum reduction strategies.

Alternative Fuel Industry Forum (2008)

- **Actions:** DOE organized an Alternative Fuel Industry Forum. Federal fleet representatives, alternative fuel providers, and alternative fuel infrastructure construction facilitators were invited to attend. Geographic analysis highlighting key areas underserved by fuel infrastructure were presented. Key speakers included representatives from GSA, DOD, and DOE.
- **Results:** Major fallout from the conference included the need to make publicly available federal fleet location data, which is currently underway.

Availability of Federal Fleet Waiver Vehicles Location Data (2008)

- **Actions:** At the request of industry representatives who attended the Alternative Fuel Industry Day Forum, DOE categorized and released location data of federal AFVs that did not have access to alternative fuel.
- **Results:** Alternative fuel providers have initiated efforts to supply fuel to federal fleets in several high-density federal vehicle geographical areas.

Federal Fleet and Clean Cities Partnership (2008)

- **Actions:** Federal fleets and Clean Cities representatives are combining efforts in selected geographical areas. Clean Cities representatives asked for and received federal fleet AFV location data.
- **Results:** Today, nearly 90 Clean Cities coalitions represent 2/3 of the nation's population and provide a local and regional forum for leveraging the efforts of the public and private sector to accelerate petroleum displacement efforts. A strong partnership exists between the federal fleet activities and Clean Cities coalitions.

Collaboration with DOD (2008)

- **Actions:** DOE is actively engaged with DOD on initiatives to reduce energy consumption through efficiency improvements and to develop sustainable energy sources for DOD installations. Transportation efficiencies are a part of this overall efficiency effort.
- **Results:** This activity further leverages the resources of federal agencies to help accelerate petroleum reduction.

(FEMP, 2008)

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APPENDIX B.

GLOBAL ELECTRIC MOTOR COMPANY (GEM, 2008)

2009 GEM Passenger Vehicles

GEM e2

Curb Weight	1,140 lbs
GVW	1,850 lbs
Payload Capacity*	710 lbs
Length	99"
Height	70"
Width	55"
Wheelbase	72"
Cubic Feet of Cab	47 ft
Turning Radius	12 ft
Tires (Street-rated)	12-inch
Range	Up to 35 miles
Top Speed (High Mode)	25 mph
Top Speed (Low Mode)	15 mph

Standard Features

- Six 12-volt flooded electrolyte batteries
- 72-volt battery system with onboard charger

GEM e4

Curb Weight	1,290 lbs
GVW	2,200 lbs
Payload Capacity*	910 lbs
Length	128"
Height	70"
Width	55"
Wheelbase	102"
Cubic Feet of Cab	78 ft
Turning Radius	16 ft
Tires (Street-rated)	12-inch
Range	Up to 30 miles
Top Speed (High Mode)	25 mph
Top Speed (Low Mode)	15 mph

Standard Features

- Six 12-volt flooded electrolyte batteries
- 72-volt battery system with onboard charger
- Sunroof

GEM e6

Curb Weight	1,620 lbs
GVW	3,000 lbs
Payload Capacity*	1,380 lbs
Length	162"
Height	71"
Width	55"
Wheelbase	133"
Cubic Feet of Cab	109 ft
Turning Radius	19.5 ft
Tires (Street-rated)	13-inch
Range	Up to 30 miles
Top Speed (High Mode)	25 mph
Top Speed (Low Mode)	15 mph

Standard Features

- Six 12-volt maintenance-free gel batteries
- 72-volt battery system with onboard charger
- Sunroof
- 7.0 hp performance package
- Grab handles
- Mud flaps
- Right hand mirror
- Scuff guards

2009 GEM Utility Vehicles

GEM eS

Curb Weight	1,170 lbs
GVW	1,850 lbs
Payload Capacity*	680 lbs
Length	108"
Height	70"
Width	55"
Wheelbase	72"
Cubic Feet of Cab	47 ft
Turning Radius	12 ft
Tires (Street-rated)	12-inch
Range	Up to 30 miles
Top Speed (High Mode)	25 mph
Top Speed (Low Mode)	15 mph

Standard Features

- Six 12-volt flooded electrolyte batteries
- 39" x 48" flat bed with a 330 lb cargo capacity
- 72-volt battery system with onboard charger

GEM eL

Curb Weight	1,255 lbs
GVW	2,300 lbs
Payload Capacity*	1,045 lbs
Length	144"
Height	70"
Width	55"
Wheelbase	114"
Cubic Feet of Cab	47 ft
Turning Radius	17.5 ft
Tires (Street-rated)	12-inch
Range	Up to 30 miles
Top Speed (High Mode)	25 mph
Top Speed (Low Mode)	15 mph

Standard Features

- Six 12-volt flooded electrolyte batteries
- 70" x 48" flat bed with a 700 lb cargo capacity
- 72-volt battery system with onboard charger

GEM eL XD

Curb Weight	1,550 lbs
GVW	3,000 lbs
Payload Capacity*	1,450 lbs
Length	144"
Height	71"
Width	55"
Wheelbase	114"
Cubic Feet of Cab	47 ft
Turning Radius	17.5 ft
Tires (Street-rated)	13-inch
Range	Up to 40 miles
Top Speed (High Mode)	25 mph
Top Speed (Low Mode)	15 mph

Standard Features

- Nine 8-volt maintenance-free gel batteries
- 70" x 48" flat bed with a 1,100 lb cargo capacity
- 72-volt battery system with onboard charger
- 7.0 hp performance package

*Options + Passengers + Cargo

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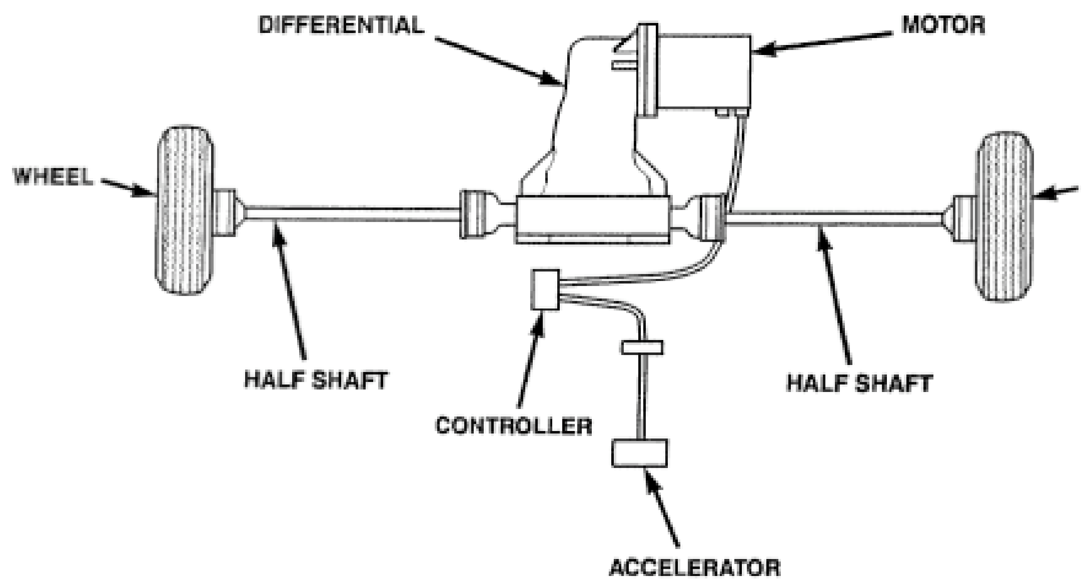
APPENDIX C.

LSV COMPONENTS (GEM, 2002)

MOTOR

Description



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APPENDIX D.

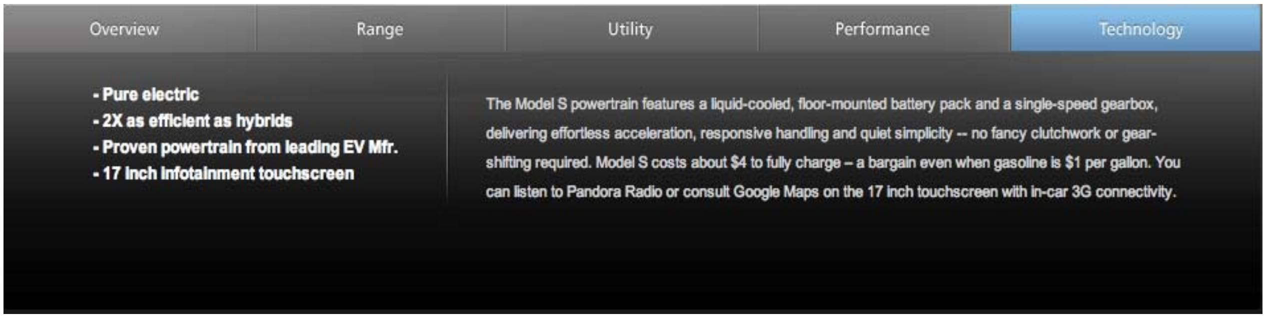
PHOENIX MOTOR COMPANY SUT/SUV

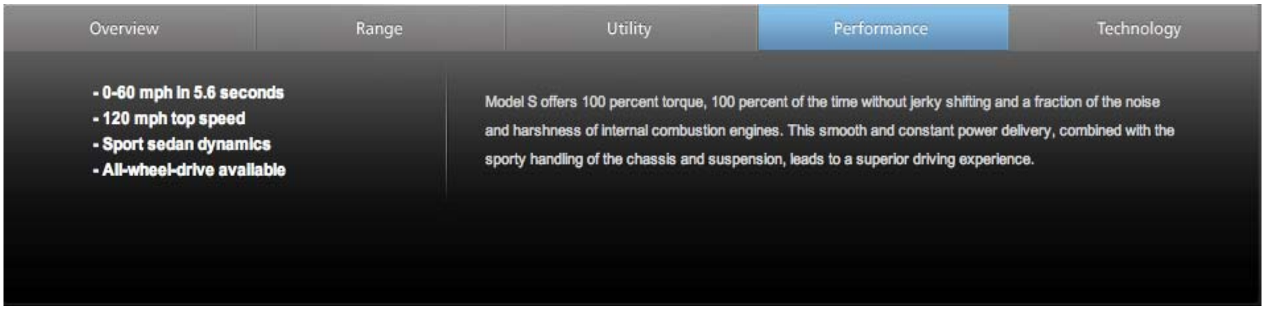
(Phoenix, 2009c)

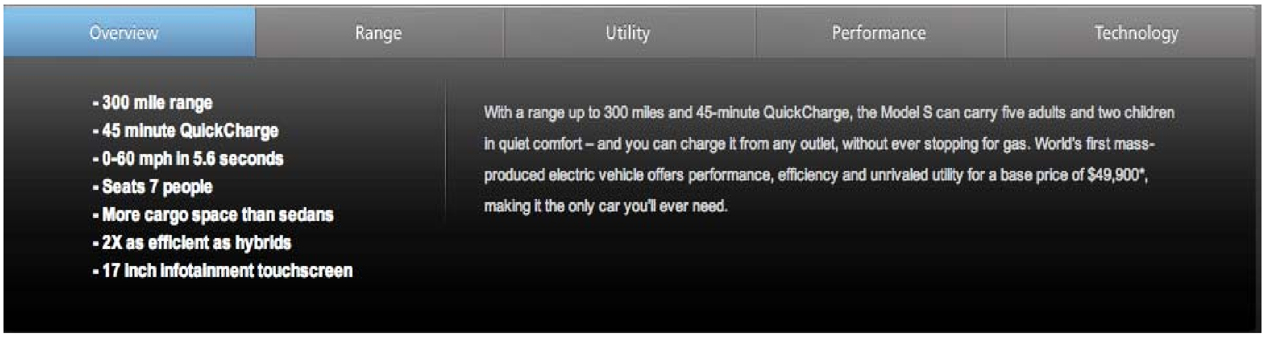
(Phoenix, 2009b)

APPENDIX E.

TESLA MOTOR COMPANY MODEL S (TESLA, 2009A)







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APPENDIX F.

CURRENT LEADING RESERVES OF LITHIUM (GAO, 2009)

Country	Reserve base[a] in tons
Bolivia	5,400,000
Chile	3,000,000
China	1,100,000
Brazil	910,000
United States	410,000
Canada	360,000
Australia	220,000

Source: U.S. Geological Survey.

[a]The reserve base is the part of the resource that meets specified minimum physical and chemical criteria related to current mining and production practices.

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APPENDIX G.

DATA COLLECTION WORK SHEET:

Interviewer Name: ____

Interviewee Name: ____

Job Title: ____

Phone #: ____

Section: ____

Discuss the different types of vehicles that we are using in our study: GEM LSV, Phoenix Motor SUV and SUT, and the Tesla Sedan.

1. What are the transport requirements of your mission?

2. Does the mission require vehicles to travel off the annex? If yes, how many of the vehicles leave the annex and how often?

3. Does the mission require vehicles to travel outside the local area? If yes, how often do the vehicles leave the local area and what are the destinations?

4. Can the mission be completed with a fleet of LSV?

5. Can the mission be completed with a fleet of electrical vehicles?

6. Can the mission be completed with a mixture of LSV and electrical vehicles? If yes, data collection is complete. If no, continue with question 7.

7. If you had to checkout a gasoline vehicle from the base motor pool to travel outside the local area would that hinder your mission accomplishment?

8. If we replaced a portion of the vehicles with a LSV for annex movements, would that hinder your mission accomplishment?

9. If we replaced a portion of your vehicles with electric vehicles for local movements (between the annexes, Barstow, and Victorville), would that hinder mission accomplishment?

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APPENDIX H.

Average kWh Produced (monthly)			
Month	**200 kWh System**	**250 kWh System**	**300kWh Sysytem**
January	23232	29040	34847
February	24756	30944	37133
March	29898	37372	44847
April	32838	41047	49256
May	31238	39047	46857
June	31125	38906	46687
July	30172	37715	45258
August	29991	37489	44987
September	29572	36965	44358
October	27488	34309	41171
November	23678	29597	35516
December	21682	27102	32523
Mean	27973	34961	41953
Std	3699	4625	5550
Range	11156	13945	16733
Cost of System	$1.2m	$1.5m	$1.8m

(Kyocera, 2009)

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